J. H. Anderson.

Modern Methods Of Highway Construction.

MODERN METHODS

OF

HIGHWAY CONSTRUCTION

BY

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I HEREBY RECOMMEND THAT THE THESIS PREPARED BY

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BE ACCEPTED AS FULFILLING THIS PART ON THE REQUIREMENTS FOR THE PROFESSIONAL DEGREE OF CIVIL ENGINEER.

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CHAPTER I.

THE PROBLEM OF HIGHWAY CONSTRUCTION.

The highway system of the United States consists of some 2,250,000 miles of public road, or approximately two-thirds mile of road per square mile of area. The improvement of this enormous system, sufficient in extent to girdle the globe 100 times, presents a problem which in many ways is the greatest that has ever confronted a people for solution. Competent authorities have estimated, however, that the improvement of 20 per cent of the total mileage will provide a trunk line or primary system, which will carry 90 per cent of the traffic. The improvement of this primary system, consisting of some 450,000 miles of road, or 1 mile of road for every 7 square miles of area, is, therefore, our first objective.

The magnitude of the highway problem can perhaps be best realized by comparison with our railroad system, to the development of which we have devoted some 70 years. The primary highway system alone exceeds the mileage of all trunk and branch railroad lines by some 40 per cent. The cost of the heavy type of construction which modern traffic makes necessary on the primary system will at least equal, and in many cases exceed, the cost of the railroads at the time of their construction. In both cost and mileage, therefore, our highway system exceeds the railroad system, considering merely that portion, some 20 per cent, herein designated as the primary system.

While it is impossible to estimate the length of time that will be required to complete our highway system, it is no doubt safe to say that a period of time considerably shorter than 70 years will be allowed by an impatient public for the completion of at least the 450,000 miles of road comprising the primary system. The value and necessity of good roads is at last fully realized, and ample funds have been provided by the public. The demand is now for a comprehensive system in the shortest possible time.

It has been estimated that approximately $1,000,000,000 are available for highway construction in 1921, while about two-thirds of this amount was available in 1920. The limiting factor to quantity production of roads to date has been the supply of raw materials, and whether or not the material supply will be adequate to permit construction at a rate commensurate with the funds available is problematical. Assuming, however, that the material situation will be properly adjusted and that funds available will be maintained at the rate for 1921, approximately 20 years will be required to complete the primary system at an average cost of $40,000 per mile. To complete the primary system in 20 years will entail construction at the rate of 24,000 miles per year. This rate of construction of trunk line highway is considerably greater than has been attained to date, so even allowing for a big increase in the rate of production, due to improved methods,

it seems that an allowance of 20 years for completing the primary system is about the minimum that good judgment dictates at the present time. Simultaneously with the construction of the primary system, a considerable amount of construction can be carried on in the cheaper types of road suitable for the secondary system.

It is not the province of this thesis to deal with the merits of any particular kind of road surfacing. Suffice it to say that the consensus of opinion among leading highway engineers at the present time is that roads with a concrete wearing surface, or a concrete base to support some other type of wearing surface, are necessary to withstand the effects of the heavy traffic which our trunk line highways will be subjected to. Inasmuch as the construction of this type of road is the most difficult and costly, this thesis will deal only with methods of construction of so-called permanent roads. The methods described in this thesis will apply to any type of road in which concrete is used either as a wearing surface or a base.

Modern heavy traffic, consisting of a vast and ever increasing number of motor trucks, requires much heavier construction and closer attention to details, than was considered necessary only a few years ago. Heavier construction naturally calls for the use of a much greater quantity of material than formerly, and the work of handling this material is consequently increased. This has led to the extensive use of machinery to replace hand methods, not only on account of greater economy and efficiency but also due to the necessity of increasing output.

At the present time we are undertaking the biggest road building program known in history, in spite of the fact that, until the winter of 1920-21, the country was suffering from an acute labor shortage and widespread unrest. No doubt this labor shortage will again make its appearance at the expiration of the present temporary period of depression. In order to overcome labor shortage, extensive use of machinery has been resorted to in highway construction. It is becoming increasingly difficult to secure labor to perform heavy manual work, and this again has led to the extensive substitution of machinery for hand methods. It has been the experience of many contractors, that labor turnover has been greatly reduced by the elimination of heavy manual labor thru the introduction of machinery. Mechanical methods also lead to the development of a higher type of labor than do hand methods.

At the present time highway construction is just emerging from the "rule-of-thumb", "hit-or-miss" stage, and for the first time scientific methods and thoro organization are being given proper consideration. Until quite recently road building has been considered a small man's game, and even now some engineers adhere to this opinion. The demand for good roads is so great, however, that it is impossible to supply it by the old methods of operation. Road building is no longer a small man's game, and it is now attracting some of the largest contracting organizations in the country. Contracts for $1,000,000 worth of work and up are now quite common. An illustration of the present trend in highway construction is afforded by Maricopa County, Arizona, where a contract for 288 miles of concrete road was awarded to one contractor in 1920.

Due to the fact that the work is spread out over such a great area and the concrete mixers are frequently many miles from the material yard, highway construction is essentially a transportation problem. Greater refinement is necessary in highway construction than in most any other class of work.

CHAPTER II.

METHODS OF HIGHWAY CONSTRUCTION

Until 2 years ago the general method of constructing a road in which concrete was used as a wearing surface or a base, has been to haul the aggregates from the material yard and dump them on the subgrade in windrows. The aggregates were then loaded into wheelbarrows by means of shovels, and wheeled to the charging skip of the mixer. This method naturally required a large number of wheelers and shovelers, the average size wheelbarrow load approximating 3 cubic feet. To load materials for a 4-bag batch of concrete of the proportions generally used, required a wheeling and shoveling crew of at least 16 men. This work was hard to perform, and the labor turnover in the charging crew was generally considerable. Occasionally a few hundred feet of 24-inch gauge track and a few dump cars were used, loading the cars by hand and pushing them to the skip of the mixer.

CHARGING MIXER BY HAND

One of the serious objections to the method of dumping aggregates on the subgrade is the cutting up of the subgrade by the wheels of the vehicles, particularly for a considerable time after a rain. Not only is the subgrade badly cut up, but serious delay is frequently incurred due to the inability of vehicles to operate over the subgrade for a number of days after a rain. In certain clay soils the delay caused by a rain will sometimes amount to a week or more. The seriousness of this lost time during the construction season is obvious.

Another serious objection to the dumping of aggregates on the subgrade is the dirt which is generally mixed with the material. The effect of this foreign matter on the quality of the pavement, particularly when a concrete wearing surface is employed, is apparent. Not only is dirt mixed with the aggregate but a considerable amount of aggregate is lost to the contractor due to rejection by the inspector because of the dirt mixed with it, and the grinding of the aggregate into the subgrade by the wheels of the vehicles employed in hauling it. A number of states now prohibit the dumping of aggregate on the subgrade.

To distribute aggregate on the subgrade in proper quantity is exceedingly difficult. If insufficient material is placed it is very difficult to replenish the supply because of the obstruction formed by the windrows of material on the subgrade. A long wheelbarrow haul generally results until additional material can be brought up. If too much material is distributed, it is generally impossible to remove the surplus without delaying the concrete mixer. The surplus, therefore, is almost always thrown on the shoulder where it is wasted.

WASTE MATERIAL ON SUBGRADE.

Dumping the aggregate on the subgrade precludes the use of a subgrade machine for trimming the subgrade, necessitating expensive and inaccurate hand trimming. The practice of dumping aggregate on the subgrade also entails a considerable amount of retrimming, due to the ruts formed by the vehicles.

WASTE MATERIAL ON SHOULDER.

Sometimes a portable belt conveyor is used in charging the concrete mixer. A typical machine of this class is that manufactured by the Koehring Machine Company, of Milwaukee, Wisconsin. This machine is equipped with a number of hoppers into which sand and stone is shoveled. Each hopper is of predetermined capacity, and discharges onto the belt by means of a door in the bottom. A conveyor belt of this type will eliminate wheelers but will require the same number of shovelers, plus an additional man or two to clear the way for moving the machine. A gasolene engine furnishes the power for the operation of the belt, and an operator must be detailed to take care of the engine. This method of construction does not eliminate dirt in the aggregates, nor waste due to dumping on the subgrade. The obstruction formed by the windrows of material likewise precludes mechanical trimming of the subgrade. While the loading belt has been used to a considerable extent during the past two years, the consensus of opinion among contractors is that this method is not economical. Naturally this method of construction cannot be used where specifications prohibit dumping material on the subgrade, or permit it to be dumped only in piles 1,000 feet or so apart.

CHARGING MIXER WITH BELT CONVEYOR

PORTABLE BUCKET LOADER HANDLING MATERIAL FROM SUBGRADE

Sometimes a small amount of light railway track is used to haul material from piles on the subgrade one-half mile or so apart. To load the batch boxes a portable bucket loader is frequently employed, as shown in the foregoing illustration. A power scraper is used to scrape material up to the bucket loader, as shown. Power for operating this scraper is obtained from the engine driving the bucket loader. This method is more economical than the method of dumping material in long windrows, as there is less chance for loss of material. The same objections due to cutting up the subgrade, delay from rain, etc. apply to this method with almost equal force as those which apply to the windrow method.

When teams, motor trucks, or tractors are used for hauling material it is necessary to begin laying concrete at the most distant point from the material yard, or at some other point between the material yard and the far end of the road provided side roads are available. This is due to the impossibility of hauling past the uncured concrete, as there is very seldom sufficient room on the shoulder of the road for the operation of teams, trucks, or tractors. When this method of haulage is employed, therefore, it is generally necessary to delay placing concrete until the grading between the material yard and the far end of the road is complete. At times this delay might be reduced by hauling material thru the grading operations, but the difficulty, and at times impossibility, of so doing in case of deep cuts or fills or the building of the road in a new location is apparent. Good side roads are difficult to find, and even when they do exist the length of haul is generally increased quite materially. The effect of hauling material over the finished grade, especially in case of wet weather, needs no comment. Not only is the placing of concrete delayed when either of the foregoing methods of haulage is employed, but when concreting is finally started the most expensive part of the work, the long haul part, is done first. This results in small payments from the state,at a time when working capital is most badly needed. The untrained organization is also required to do the most difficult part of the work first.

The latest and most modern method of building roads on a large scale, is by means of the light railway method. In this method a light railway is employed to haul material in batch boxes from the material yard directly to the mixer. Two batch boxes are generally carried on each car, each box containing complete materials for a batch of proper size for the mixer. On arrival at the mixer each box is picked up by means of a small derrick attached to the mixer, and the batch boxes dumped directly into the skip. With this system materials never touch the subgrade at all.

DIRECT CHARGING OF MIXER BY MEANS OF LIGHT RAILWAY.

In place of the wheeling and shoveling gang of 16 or more men necessary in the old method of building roads, only 2 or 3 men are needed to charge the mixer by means of the batch box and light railway system. The resulting economy of 13 or 14 men, at the present high price of labor, amounts to a large sum in the course of a season. Due to the fact that aggregates are not dumped on the subgrade, loss of material and the picking up of dirt is eliminated. Minimum delay from rain is insured, while it is possible to start work earlier in the spring than if a method of construction is used which depends upon haulage over earth roads. The unobstructed subgrade permits machine trimming to be performed, thus reducing the cost of trimming and eliminating loss due to the placing of extra concrete resulting from inaccurate subgrade.

MACHINE TRIMMING OF THE SUBGRADE

Light railway haulage permits the laying of concrete to begin at the point nearest the material yard, inasmuch as hauling can be performed past the uncured concrete on the shoulder of the road. The laying of concrete can begin as soon as a few hundred feet of subgrade have been prepared, and can follow immediately behind the grading operations without interference. This eliminates the delay that generally occurs in placing concrete when a system of haulage is used which cannot operate past the uncured concrete. Not only can the placing of concrete and the operation of grading be carried on simultaneously, but the most profitable portion of the concrete, the short haul portion, is done first. A large payment from the State early in the life of the job is thus insured, providing the working capital generally so badly needed at this time. Furthermore, by the time the long haul portion of the job is reached, the organization is experienced and the track is well bedded.

Another method of construction which has come into quite general use during the past 2 years, is to haul properly proportioned batches in motor trucks and dump directly into the skip of the mixer. Dump body trucks of 3 and 5 ton capacity, with the bodies partitioned off so as to form compartments for a number of batches, are sometimes used. The difficulty of handling these heavy units on the subgrade, particularly of turning them, and their destructive effect on the subgrade, has led to the use of light trucks, such as the Ford. These light trucks are equipped with oversize tires, and with special dump bodies arranged to dump to the rear. A number of patented types of dump bodies are on the market at the present time, among them the Lee body and the Hanson body. The Ford truck

possesses the advantage of being easily turned by means of a light turntable, and of not cutting up the subgrade as badly as the larger truck. The disadvantage of the light truck system over the heavy truck system is the larger number of units and drivers required, as well as the rapid depreciation of the light machines. The objection to all truck systems is the delay caused by wet subgrade, the cutting up of the subgrade, and the fact that the placing of concrete must begin at the point farthest from the material yard. As mentioned in a previous paragraph this results in considerable delay, and in minimum payments from the State just at a time when money is most badly needed.

CHARGING MIXER DIRECT FROM TRUCK

MOTOR TRUCKS HAULING MIXED CONCRETE

In some parts of the country the central mixing plant method of building roads has been used to a certain extent. When this method is employed, the mixed concrete is generally hauled out to the road by means of motor trucks, as shown in

the above photograph. The trucks shown in the photograph are 5 ton units, hauling about 2 cubic yards of concrete per trip in a special dump body. The difficulty of removing the concrete, and the planks on the subgrade necessary to prevent rutting, are clearly shown. Considerable segregation of the concrete occurs, especially if the consistency is wet. The use of a mechanical finishing machine, shown in the lower right hand corner of the photograph, permits a dryer consistency to be used, and obviates to a certain extent the objections to the central mixing plant method. In the central mixing plant method there is always the danger that too great a length of time will elapse between the mixing of the concrete and the placing of it on the road. With this method it is also necessary to delay the placing of concrete until a good deal of the grading has been completed, and to begin the placing of concrete at a point farthest from the material yard. The possibility of delay, due to wet subgrade and the cutting up of the subgrade by the motor trucks, is another objection to the central mixing plant plan.

The central mixing plant method of construction has been used in a few instances with the light railway system of batch box haulage. The mixed concrete has been discharged directly into batch boxes of the steel, tip-over type, and hauled to the road in the regular manner. A crane picked up the loaded boxes from the cars and swung them over the subgrade where they were dumped by 2 men. In order to remove the packed concrete from the corners, a small air compressor was installed on the crane. The photograph below shows the method of dislodging concrete from the corners of the box by means of the compressed air method. A pressure of 50 to 60 pounds per square inch has been found sufficient. The same objection to the segregation of the concrete and the possibility of too long a time elapsing between the mixing and finishing operations, can be brought against the central mixing plant when light railway haulage is employed as when motor truck haulage is used.

LIGHT RAILWAY HAULING MIXED CONCRETE

In the opinion of many contractors, aside from reliability of operation due to greater independence of weather conditions and the saving in labor, the biggest advantage of light railway haulage is the possibility of carrying on concreting and grading operations simultaneously. This insures a large payment early in the life of the job, which provides much needed working capital.

Until the summer of 1919 hand methods were universally employed in striking off and finishing concrete road, and concrete base for other types of pavement. At that time the first successful mechanical finishing machine, that of The Lakewood Engineering Company, of Cleveland, Ohio, was introduced, and at the present time between 400 and 500 of these machines are in use. This machine not only strikes off the concrete, but subjects it to an intensive tamping action. Dryer mixtures can thus be used, resulting in denser and stronger concrete according to the researches of Professor Duff Abrams, of Lewis Institute, Chicago. Not only does the mechanical finishing machine produce a better pavement but it saves the labor of 2 or 3 men for the contractor. A number of State Highway Departments at the present time either specify machine finishing for concrete roads, or offer special concessions to the contractor to induce him to use a finishing machine.

LAKEWOOD ROAD FINISHING MACHINE

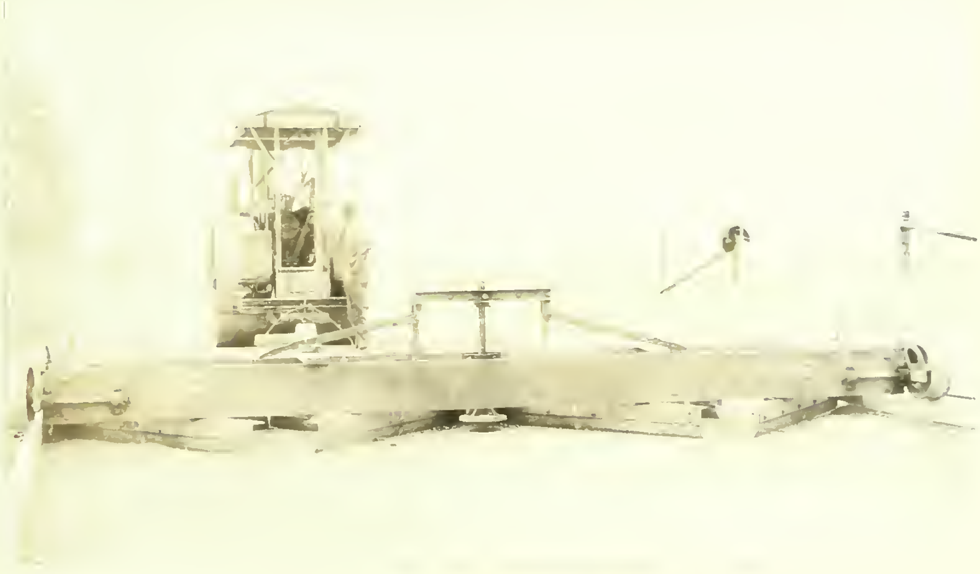
The finishing machine shown in the foregoing illustration is well adapted to the construction of brick pavements, especially of the monolithic type. It is employed to strike off and tamp the concrete base and to tamp the brick, thus producing a much smoother job than is possible by hand methods. In speaking of the use of the finishing machine in monolithic brick road construction in Engineering News-Record for January 6, 1921, Mr. W. M. Watson, State Highway Engineer of Kansas, states as follows:

> "At the beginning of the work the base was poured at a stiff consistency and struck off by the Parrish type of multiple steel templet, using a 3/16" dry sand-cement bed. The brick were laid directly on the sand-cement bed before the base attained its initial set. The gravel aggregate, containing very little coarse material, produced a concrete with which it was difficult to obtain satisfactory results. When mixed sufficiently dry to permit the other operations it contained too little water properly to saturate the dry cushion, with a consequent separation between the base and brick surface. When made with enough water to give the dry cushion the proper amount of water, due to the absence of coarse material, the concrete had little stability, rendering the operations of rolling and grouting exceedingly difficult and

making it almost impossible to secure a smooth surface. This trouble has been overcome by the use of a mechanical tamping machine operated directly on the base, and by eliminating the sand-cement cushion. A marked improvement is noted by reason of this change, not only in the surface of the pavement but in the adhesion as well. Not only does mortar tamped to the surface, firmly adhere to the brick, but from 1/4" to 1/2" of mortar squeezes up between the bricks, giving greater assured resistance to the sliding of the brick along the base, due to difference in coefficient of expansion. A much denser concrete in the base is also assured."

Complete specifications of the Lakewood finishing machine will be found in the appendix to this thesis. To secure the best results with a finishing machine it is necessary to use steel forms weighing not less than 6-1/2 pounds per foot exclusive of fastenings.

A machine for trimming subgrade has been developed by The Lakewood Engineering Company and is now extensively used. This machine operates on the side forms and is generally pulled by means of the road roller, as shown in the following illustration.



LAKEWOOD SUBGRADER

One of the most troublesome and expensive operations performed in road building is that of trimming the subgrade, and by hand methods it is seldom possible to secure a surface closer than one-fourth inch of the correct contour and elevation. With the rigid inspection characteristic of road building today, the subgrade is generally cut too low. Loss due to low subgrade is one of the most prevalent and difficult to overcome when subgrade is trimmed by hand. Machine trimming will produce a subgrade practically as accurate as the finished pavement. When we stop to consider that a subgrade one-fourth inch too low results in placing 75 cubic yards of concrete per mile of 18 foot road for which no pay is received, and concrete is worth from $15.00 to $22.00 per cubic yard, the possibility of loss from this source is apparent. Machine trimming of the subgrade not only results in greater accuracy, but in less cost than hand trimming.

In the past but little attention has been paid to the problem of insuring a reliable and adequate water supply, in spite of the fact that the cost of a good pump is but a ~~few~~ small per cent of the cost of the plant, whose operation depends entirely on it. Happily, the importance of insuring a proper water supply is now fully realized by progressive highway contractors, many of whom are using a double unit pump. The double unit pump consists of 2 complete pumps and gasolene engines mounted on a truck, so arranged that either pump can be operated independently of the other or both pumps together if desired.

The use of a pipe line of inadequate capacity is one of the most expensive mistakes which a highway contractor can make, for this will off-set any provision he has made for adequate pumping capacity. A pipe line not less than 2 inches in diameter should be used to furnish water for a half yard or three-quarter yard paving mixer, wet batch rating, and a pipe line preferably of 2-1/2 inches diameter for a cubic yard mixer. Gate valves should be provided every half mile, and unions every 1,000 feet. Provision must be made for taking care of expansion and contraction in the pipe line, either by means of a patented expansion joint such as that manufactured by the C. H. & E. Manufacturing Company, of Milwaukee, Wisconsin, or by means of a home made device consisting of a short section of hose. Tees should be inserted in the pipe line approximately every 100 feet to permit attachment of the hose leading to the paving mixer. While we are considering the subject of pipe lines, it is desired to point out that a central mixing plant will not eliminate the necessity for employing a pipe line and pump because water must be supplied for curing the concrete.

To supply water for a half yard or three-quarter yard paving mixer plant, including water for sprinkling the subgrade and curing the concrete, the pump should be capable of delivering a supply of at least 30 to 40 gallons per minute at the end of the pipe line. In order to supply this amount at the end of 3 miles of new 2 inch wrought iron pipe, a pressure of about 225 pounds per square inch must be maintained at the pump in level country.

We can sum up the modern method of road building briefly by stating that the tendency is to replace hand methods by machine methods wherever possible. This machinery is of a much better type than that formerly considered good enough for construction work, and the units are not selected in a haphazard fashion. The modern road building plant consists of a number of high class, properly balanced, and coordinated units, designed to operate as a whole. Road building is rapidly becoming a highly organized manufacturing business, for after all a road builder is a manufacture assembling his raw materials into the finished product thru the medium of machinery. The business of road building is rapidly assuming the highly organized methods of the manufacturer.

CHAPTER III.

RATE OF CONSTRUCTION

The rate of construction obviously depends upon the type of road, and upon the quantity of material contained in it. This brings us to the consideration of a mistake frequently made in computing quantities of material, namely assuming the average thickness of a road with a crowned surface on a flat subgrade to be the mean between the side and center thickness. If the surface of a road is a plane this assumption would be correct, but the surface is generally parabolic or cylindrical. Due to the long radius, there is practically no difference in the average thickness of a road having a cylindrical or a parabolic surface. Assuming the surface to be parabolic, a formula can be derived for the average thickness. This formula can be expressed in terms of the mean of the side and center depths, plus one-sixth of the crown. For instance, a road 6 inches thick at the sides and 8 inches at the center on a flat subgrade has an average depth of 7-1/3 inches. In case the subgrade is crowned in a different manner from the surface of the pavement, the average thickness is equal to the mean between the side and center depths plus one-sixth of the difference between the surface and subgrade crowns. Inasmuch as an increase of 1/3 inch in the average depth amounts to almost 100 cubic yards of concrete per mile of 18 foot road, the seriousness of assuming the average depth as a mean between the sides and the center is apparent.

A road 6 inches thick at the sides and 8 inches thick at the center on a flat subgrade has an average thickness of 7-1/3 inches, as shown in the preceding paragraph. On such a road 1 cubic yard of concrete will produce 4.91 square yards of pavement. An 18 foot road of this type contains 0.407 cubic yards of concrete per lineal foot, or 2,150 cubic yards per mile.

Based upon a weight of 376 pounds per barrel of cement, 3,000 pounds per cubic yard of sand, and 2,700 pounds per cubic yard of stone, the quantity of material required per mile of 18 foot concrete road of a 1-2-3 mixture, 6 inches thick at the sides and 8 inches thick at the center, is as follows:

3,762 bbls. cement or	707 tons
1,118 cu.yds. sand or	1,677 "
1,677 cu.yds. stone or	2,264 "
Total	4,648 tons

The rate of construction naturally depends to a certain extent upon the size of batch used in the concrete mixer, but more upon the efficiency of the organization. Practically all state highway specifications set a time limit of not less than 1 minute for mixing concrete, and this time limit is the big factor to consider in determining output. When a time limit of 1 minute is specified it is possible for a good organization to produce 40 batches of concrete per hour with a one-half or three-quarter yard paving mixer without violating specifications. Experience indicates, however, that 30 batches per hour is a good rate of operation for this size of mixer, and a good organization with an adequate supply of materials should maintain this rate. With a 1 cubic yard paving mixer it is not wise to count on more than 24 batches per hour. It must be clearly understood that the rate of operation given in this paragraph is the actual rate which should be obtained under normal conditions, and is not inclusive of unusual delays.

In order to overcome the confusion which existed a few years ago with respect to the capacity of concrete mixers, the National Association of Mixer Manufacturers have adopted a standard system for designating the capacity of mixers. At the present time a system of numbers and letters is used which indicate not only the capacity of the mixer, but also the type. The numbers indicate the cubic feet of mixed concrete which a mixer can handle per batch under normal conditions, while the letters indicate whether the mixer is a side loader and side discharge machine or an end loader and end discharge machine. The side loading and side discharge machines are building mixers, while the end loading and end discharge machines are paving mixers. For instance, a 14-E mixer indicates a paving mixer, having a capacity of 14 cubic feet of mixed concrete per batch, while the 21-S mixer indicates a building mixer having a capacity of 21 cubic feet of concrete per batch. The amount of dry materials required to produce a certain amount of mixed concrete, is approximately 50 per cent greater than the volume of the mixed concrete.

At the present time the tendency is toward the use of larger paving mixers, for a large machine can be operated with practically no more men than a small machine. The 10-E, 14-E, and 21-E machines are the types most commonly employed in highway construction at the present time. The 28-E machine is rapidly coming into favor, however, and promises to become the most popular type within a few years. The 10-E machine is entirely too small for quantity production of roads, and the manufacture of this type has now been discontinued by most manufacturers. The 14-E and 21-E sizes are employed on perhaps 95 per cent of the work today.

The size of a batch of concrete is generally expressed in terms of the number of bags of cement which it contains, such as a 3 bag or 4 bag batch. Naturally the number of bags of cement which can be placed in one batch depends upon the capacity of the mixer,and the proportions. For instance, a 14-E mixer can be used to mix a 4 bag batch of 1-2-3 concrete, producing 15.6 cubic feet, inasmuch as all mixers are designed with a normal overload capacity. To mix a 5 bag batch of 1-2-3 concrete, amounting to 19.5 cubic feet, will require a 21-E mixer. A 28-E mixer is capable of mixing a 7 bag batch of this mixture. On the other hand if the concrete is to be mixed in the proportions of 1-2½-5, a 14-E mixer can handle only a 3 bag batch, etc.

At a rate of 30 batches per hour, a 14-E mixer handling a 4 bag batch of 1-2-3 concrete will produce 17.4 cubic yards. At this rate the output in 10 hours would be 174 cubic yards, equivalent to 854 square yards of concrete averaging 7-1/3 inches in thickness. Such an output is equivalent to 427 lineal feet of 18 foot road. To allow for minor delays we will call the daily output 400 feet of road of this type.

In estimating the monthly output it is not wise to assume more than 20 working days per month during a normal season. At a rate of 400 feet of road per day, a 14-E mixer should produce 8,000 feet or 1-1/2 miles per 20 day month. To allow further for contingencies, experience indicates that the monthly output of a 14-E mixer on the type of road we have assumed should not be taken to exceed 1-1/4 miles under normal conditions. Sometimes it is wise not to count on more than 1 mile of 18 foot concrete road,having an average thickness of 7-1/3 inches, per month from a 14-E machine. These outputs are based upon normal conditions, and might be materially altered one way or the other by weather conditions, material supply, etc. Local conditions must be considered and individual judgment exercised in estimating the probable rate of construction on any job, but a good organization with an adequate supply of materials should produce the outputs mentioned in this paragraph.

The amount of road produced per season depends largely upon the length of the working season, which in turn varies with climatic conditions. In the Middle West a working season of 5 or 6 months is all that can be depended upon, while in California and parts of the South the working season is frequently twice as long. With a working season of 5 or 6 months a good organization with an adequate supply of materials should produce from 6 to 7½ miles of standard 18-foot concrete road under normal conditions with a 14-E mixer. A 21-E mixer should produce from 8 to 9 miles of standard concrete road in a normal season, while a 28-E mixer should produce from 10 to 12 miles. A standard concrete road is considered to be 18 feet wide, with an average thickness of 7-1/3 inches.

The output of road per working season depends upon many factors other than the capacity of the mixer, chief among which are the organizing ability of the contractor and the supply of raw materials. Many cases are known where a 14-E paving mixer is producing only 250 lineal feet of 18 foot concrete per 10 hour day, whereas the same type of machine working under practically the same conditions a few miles away is producing from 400 to 500 feet. It is true that during the past two years the output of road has been seriously limited by the shortage of raw material, and by erratic and inefficient railroad service. Nevertheless the biggest limiting factor in road production has always been, and still is, poor organization. Some men will take a second hand concrete mixer and a few wheelbarrows and make a success of highway construction, while others will fail even though equipped with the most modern machinery. In highway construction, as in every other human activity, the personal element enters largely into the final results.

To show the possibility of producing roads in quantity, a few examples selected at random from various sections of the country will be given:

In 1919 the Bates & Rogers Construction Company, of Chicago, averaged 440 lineal feet of standard Illinois 18 foot concrete road per day for 3 weeks with a 14-E mixer in one run. On another occasion they averaged better than 460 feet per day for 10 days. These performances were given me during a conversation with a member of the firm, and undoubtedly they were duplicated or exceeded many times. In 1920 this same firm laid as high as 490 feet of concrete road 17 feet 4 inches wide averaging 9-1/3 inches in thickness in 10 hours with a 14-E mixer for the Ohio State Highway Department.

In 1920 and 1921 Twohy Brothers, of Portland, Oregon, operating on a 288 mile concrete road contract in Arizona, frequently placed 500 feet of 18 foot concrete road of a 1-2-4 mix and 7-1/3 inch average thickness in 8 hours. A 14-E Lakewood paving mixer was used, supplied with a light railway haulage system. The photograph on page 6 shows one of the mixing plants on this job. Note the small organization required to operate this plant.

Allen J. Parrish, of Paris, Illinois, in 1920, produced as high as 790 feet of standard Illinois 18 foot concrete road with a 21-E Smith paving mixer in 10 hours. His average output for 14 consecutive working days was 565 feet, while his output thruout the season averaged well over 450 feet per working day. Mr. Parish used a 5 bag batch of 1-2-3½ concrete, and in order to produce 790 feet of road in 10 hours it was necessary to maintain an output of about 40 batches per hour thruout the day. In speaking of Mr. Parrish's accomplishment Engineering News-Record for January 6, 1921, states as follows: "Explanation of this continuous good progress lies in the one word management, which includes keeping the supply of materials constant."

Johnson, Drake & Piper, of Minneapolis, built an average of 590 lineal feet of 18 foot concrete road for 23 days in the month of October, 1920. The total output for the month amounted to 2.37 miles. This was accomplished by hauling out properly proportioned batches in trucks, and dumping directly into the skip of the 1 cubic yard mixer. The type of road was concrete 18 feet wide, of a 1-2-4 mixture, and an average thickness of 7-1/3 inches.

Siems, Helmer, & Schaffner, of St. Paul on state road work in Minnesota, have produced as much as 1,072 lineal feet of 18 foot concrete road in 10 hours. Properly proportioned batches were hauled out in batch boxes by means of light railway, and were dumped directly into a specially arranged 28-S Lakewood building mixer. This work was performed during the season of 1920.

Another Minnesota firm, McCree-Moos, of St. Paul, laid 1,098 feet of 18 foot concrete road in 10 hours during the season of 1920. A central mixing plant consisting of a 1 cubic yard building mixer was used to mix the concrete, which was hauled to the road by means of motor trucks.

Mr. G. P. Scharl, of Muskegon, Michigan, operating a 28-E Koehring mixer supplied by means of the light railway and batch box system, has produced 1,031 lineal feet of 18 foot concrete road in 10 hours. This road was 18 feet wide, of a 1-1½-3 mixture, and an average thickness of 7-1/3 inches. Mr. Scharl's best weekly output was somewhat over 5,000 feet, while his monthly output has run as high as 2-1/2 miles. This work was performed in 1920.

The Henry W. Horst Company, of Rock Island, Illinois, operating on standard Illinois concrete road 16 and 18 feet wide near Vandalia, Illinois, during the season of 1920, frequently laid 600 feet of road in 10 hours. Mr. Horst used Ford trucks to haul properly proportioned batches and dump directly into the skip of the paving mixer. A central mixing plant was also used in conjunction with Ford trucks, and the output of each method was just about the same.

James O. Heyworth, of Chicago, in building an 18 foot concrete road for the Illinois State Highway Department, during the seasons of 1919 and 1920, frequently laid 500 feet in 10 hours with the light railway system. Mellon-Stuart, Nelson Company, of Chicago, operating on standard 18 foot Illinois concrete road near Desplaines, Illinois, laid from 600 to 700 feet of road in 10 hours. A light railway system manufactured by the Western Wheeled Scraper Company, of Aurora Illinois, was used to haul properly proportioned batches in batch boxes to the 21-E mixer.

Thomas Fitzgerald, of Ashtabula, Ohio, during the season of 1919, laid 11.92 miles of monolithic brick road 16 and 18 feet wide in 92 working days for the Ohio State Highway Department, with two 14-E mixers.

George Walters, of Butler, Penna. laid from 525 feet to 588 feet of 16 foot reinforced concrete road of a 1-2-3 mixture and an average thickness of 7-1/3 inches, in 10 hours. This work was performed in the summer of 1920 for the Pennsylvania State Highway Department, using a 14-E Rex mixer. The minimum time limit in Pennsylvania for mixing concrete is 1-1/4 minutes.

The Quinlan-Robertson Company, of Montreal, Canada, in 1920 have laid from 600 to 700 feet of standard 18 foot Pennsylvania reinforced concrete road in 10 hours. A light railway haulage system was used to haul material in batch boxes to a 28-E Koehring paver.

Elder & Company, at Georgetown, Delaware, laid as high as 781 feet of 14 foot concrete road, having an average thickness of 6-1/3 inches, in 10 hours during the season of 1920. This work was performed for the Delaware State Highway Department. A 28-E Koehring mixer was used to mix the concrete, which was of 1-2-4 proportions.

The Chicago Heights Coal Company, at Momence, Illinois, and the J. J. Dunnegan Construction Company, at Morrison, Illinois, have produced from 450 to 550 lineal feet of 18 foot standard Illinois concrete road in 10 hours, during the seasons of 1919 and 1920. The light railway system of haulage was used to supply 14-E Lakewood paving mixers.

It is by no means intended to convey the impression that the output of road mentioned in the preceding paragraphs was maintained every day thruout the season. They were merely mentioned to show the possibility for quantity production open to a contractor of good organizing ability, and as an answer to those who claim that from 250 to 300 feet of road per 10 hour day is all that can be expected. The fact that the records mentioned above were made during the periods of acute material and labor shortage prevailing in 1919 and 1920, is all the more reason to assume that these records will not only be frequently duplicated but greatly exceeded during the normal times which seem to be approaching. As in the case of Mr. Parrish, the explanation of the foregoing records is given by the one word management, though undoubtedly a properly balanced and coordinated road building plant was a contributary cause. The selection of the proper road building plant, however, can also be considered as coming under the head of good management.

Heretofore contractors have paid but little attention to the problem of insuring an adequate supply of raw materials during the working season, by storing material during the inactive months. The general practice has been to depend more or less upon day to day delivery from the producer and the railroad. The danger of such practice has been most forcefully presented during the acute material shortage and inefficient and erratic railroad service prevailing the past two years. A manufacturer who undertook business without adequate preparation in the way of stock on hand, would not be considered a man of good business judgment. A contractor is nothing more nor less than a manufacturer of roads, and failure on his part to adequately prepare for the construction season by storing material is no more excusable than it would be on the part of the manufacturer of any other article. State Highway Departments, profiting by the experience of the past two years, now realize the necessity for a contractor's preparing himself for the construction season by storing material during the winter months. In the past the biggest handicap to this practice has been the large amount of working capital tied up. In order to overcome this handicap and induce contractors to store material during the inactive months, most states have made provision in their specifications for monthly payments on stored material. This should go a long way toward inducing contractors to store material, and a resulting decreased delay during the construction season should mean a greater output of road.

In the fall of 1919 the Lakewood Engineering Company, of Cleveland, Ohio, sent letters to a large number of material producers thruout the country, asking them their opinion of winter storage of materials. Many producers replied that it would be impossible or very difficult to operate all winter, but the consensus of opinion of about 100 producers thruout the country was to the effect that they could operate at least 2 or 3 months longer than they do at present if contractors would store material during the inactive months. In the fall of 1920 the Lakewood

Engineering Company again sent out hundreds of letters to State Highway Departments, Bankers, Material Producers, Contractors and Railroad Officials on the subject of winter storage of road building material. The consensus of opinion from all classes was that winter storage is not only desirable but necessary if the production of roads is to be adequate to the demands. The progressive contractor, therefore, who desires to insure himself against delay during the construction season, should have no difficulty at the present time in financing winter storage of materials. It is realized that the storage of materials during the most severe weather in many parts of the country is very difficult, but it is almost always possible to store materials for a month or two before severe winter weather sets in and for the same length of time in the early spring before the season is sufficiently advanced to permit laying concrete.

The storage of cement is much more difficult than the storage of sand or stone, because of the possibility of spoiling. Many states, however, will permit cement to be stored after a certain date, among them Pennsylvania which permits this practice after February 15th. Many contractors have suffered loss in the past due to improper storage of cement. A good discussion of this subject appeared in Engineering News-Record for December 2, 1920 by Mr. Blain S. Smith, General Sales Manager for the Universal Portland Cement Company, of Chicago. In this discussion Mr. Smith pointed out that not only should the cement shed have weather tight walls, floor and roof lined with building paper, but the cement should be so piled as to prevent the circulation of air, for air carries moisture. In order to prevent circulation of air it is wise to cover the cement with building paper or canvas. If the precautions recommended by Mr. Smith are observed, a contractor should run but little risk in storing cement. When payments are made on cement by State Highway Departments, no allowance is made for sacks. Bulk cement possesses a big advantage in this respect, because a contractor is not called upon to tie up his money at the rate of $1.00 per barrel for the non-productive item of sacks.

Experience during the past two years has shown the fallacy of awarding more work than can be completed in one season, for the effect of this practice is to create a serious material shortage and to delay the progress of all contractors. Another result of this practice is to cause an increase in contract prices. Contractors who secure the work late in the season can thus afford to pay more for material and labor than those who were awarded work earlier in the year, to the detriment of the latter. Based upon their experience during the past two years the Pennsylvania State Highway Department, one of the best organized in the country, has concluded that about 500 miles of trunk line concrete road is about all they can expect at the present time per working season. It is quite probable of course that as contractors realize more fully the need of proper preparation for the construction season by storing material during the winter months, that this limit of 500 miles per year will be considerably increased. Until the Pennsylvania Department is convinced that conditions have changed sufficiently, they intend to limit their yearly awards to 500 miles of road. The standard type of trunk line road in Pennsylvania is reinforced concrete of a 1-2-3 mixture, 18 feet wide, and of an average thickness of 7-1/3 inches. A minimum time limit of 1-1/4 minutes for mixing is specified.

In the introduction to this thesis an estimate was given of the probable length of time required to complete our primary highway system of 450,000 miles. This estimate was based upon funds available of $1,000,000,000, and an average cost of $40,000 per mile. It is interesting to note that if all states were building roads at the rate which Pennsylvania considers proper, that this would result

in an output of 24,000 miles of trunk line highway. This is the same figure arrived at in the previous estimate. Even allowing for increased production due to improved equipment, improved material supply, and better management on the part of contractors, it would seem that an output of 24,000 miles of trunk line highway per year will not be attained for some time. It seems reasonable to suppose, therefore, that at least 20 years are necessary for the construction of our trunk line system of 450,000 miles.

In addition to encouraging contractors to store materials during the winter months by paying for material as delivered, State Highway Departments can greatly assist in increasing the production of roads by awarding contracts early and in large sections. The use of light railway haulage should also result in an increased yearly output, because work can be started earlier in the spring than if hauling must be performed over earth roads and the delay from rain should be reduced to a minimum.

In the final analysis the output of roads will depend upon the managing ability of the contractor, though it is fully realized that some factors, such as poor railroad service, are largely beyond his control. Even here, however, the good manager will take precautions which will minimize as much as possible delay from this source. The contractor who is a good manager and a good organizer will generally secure good results no matter what method or what type of equipment he will employ, though it is reasonable to suppose he will secure better results with some methods and equipment than with others. The contractor who is a poor manager on the other hand will not secure good results, as a rule, no matter how elaborate or costly his equipment may be. In road building, as in all operations, the human element enters largely into the final results.

CHAPTER IV.

THE APPLICATION OF LIGHT RAILWAY TO HIGHWAY CONSTRUCTION.

The idea of using light railway haulage in highway construction is not a new one by any means, and attempts have been made from time to time in the past to use this method of haulage. Until two years ago, however, most of the attempts to use light railways have been rather unsuccessful from the standpoint of both cost and operation. This was due principally to the use of very poor track, and rolling stock intended primarily for railroad construction. This equipment was too heavy and inflexible for the class of work it was called upon to perform in road building. The motive power consisted of four wheeled steam locomotives weighing from 12 to 20 tons. These heavy machines soon warped the light track so badly that frequent derailments and many delays were caused. A very light type of track was used with short, narrow, open-end corrugated ties, and rail weighing only 12 to 16 pounds per yard. These ties did not have sufficient bearing area to support the heavy concentrated loads imposed by the locomotives, nor did the rail possess sufficient beam strength to carry the load between ties without warping. The rails were fastened to the ties by means of clips, resulting in a track of but little rigidity. The photograph below illustrates some of this badly warped track.

EFFECT OF HEAVY ROLLING STOCK ON LIGHT TRACK

Another reason for lack of success in the past with light railway haulage, lay in the use of V-body dump cars and paving mixers with side loading skips. Unless the track was at the proper elevation and location with respect to the loading skip it was very difficult to dump material into the skip, and in any event it was generally necessary to detail several men to scrape the cars clean. The space required by these side loading paving mixers was so great that it was generally necessary to straddle one of the side forms, while the form on the side next to the track could only be placed one section at a time as the mixer moved.

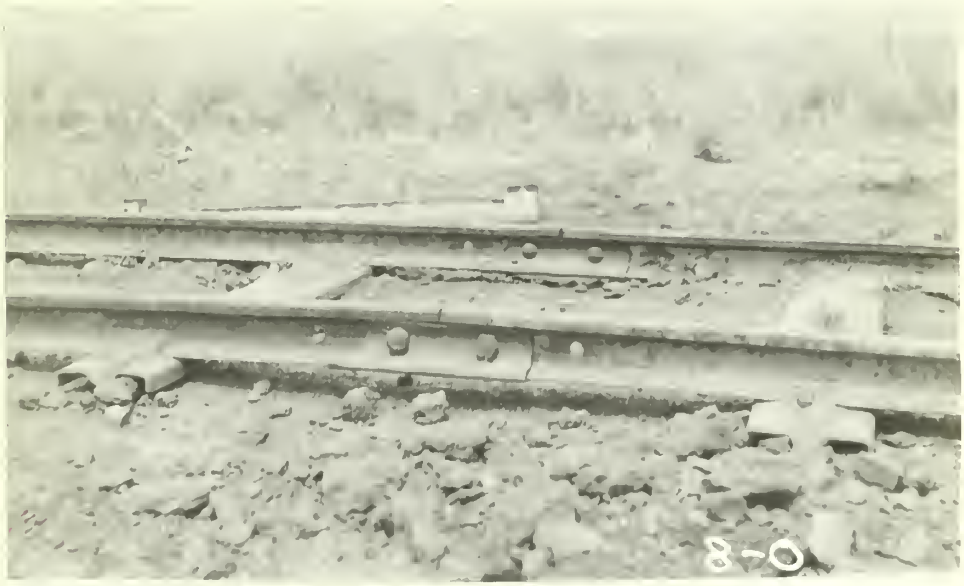
V-BODY CARS CHARGING SIDE-LOADING PAVING MIXER

Some years ago when light railway haulage was first thought of in connection with highway construction, material was frequently dumped on the subgrade in long windrows in the same manner as when teams or trucks were used. The possible saving of labor in charging the mixer directly from the railway cars so as to eliminate the wheeling and shoveling crew, was not taken advantage of. The railway method, therefore, did not possess any advantages over any other method, as far as labor at the mixer was concerned. The sole advantage of the railway method at that time was elimination of rutted subgrade, and the somewhat more or less increased reliability of operation due to the fact that haulage could be performed in spite of wet roads. Delays from derailment were so frequent, however, with the makeshift equipment used that increased reliability over other methods was at least questionable, while the investment required was considerably greater.

DERAILMENT RESULTING FROM POOR TRACK AND EQUIPMENT

The old conception of highway construction failed to recognize the fact that hauling is but one of many operations performed by the contractor, though next to providing an adequate supply of raw material it is the most important one. But even so the cost of hauling, alone, is not the proper criterion by which to judge the merits of a plan of operation. If the only function the contractor had to perform was to haul material from one point to another, then the cost of hauling per ton mile would be the proper criterion to use in judging the merits of a plan. Any method of operation which entails unnecessary labor at the mixer, on the subgrade, etc. is not good, even though the cost of performing one of the functions, such as hauling, is low. In other words a road building plant must be considered as a whole, and it must be judged by its performance as a unit and not simply by the performance of one of its parts. Failure to recognize this fact was one of the contributing causes to the lack of success which characterized early attempts to apply light railway haulage to highway construction.

The back-bone of any railway system, especially a light railway system, is the track. It is possible to operate poor equipment over good track with success, as far as the track is concerned, but it is not possible to operate even the best of equipment over poor track with any degree of success. Not only should the track be adequate to carry the loads imposed upon it without permanent distortion, but it should be properly laid and maintained at all times. Without proper attention to laying and maintenance, even the best track will not prove satisfactory. Aside from the fact that the track used was of improper design and inadequate capacity to carry the loads imposed upon it, failure to properly lay and maintain it was one of the big causes for the lack of success which attended early attempts to apply light railway haulage to highway construction.

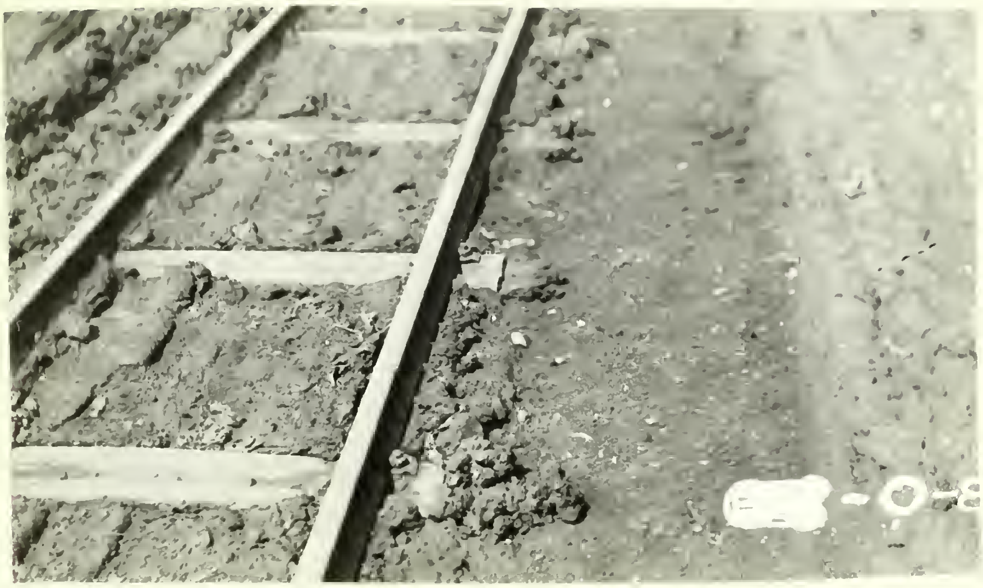


OLD STYLE TRACK OF INADEQUATE CAPACITY

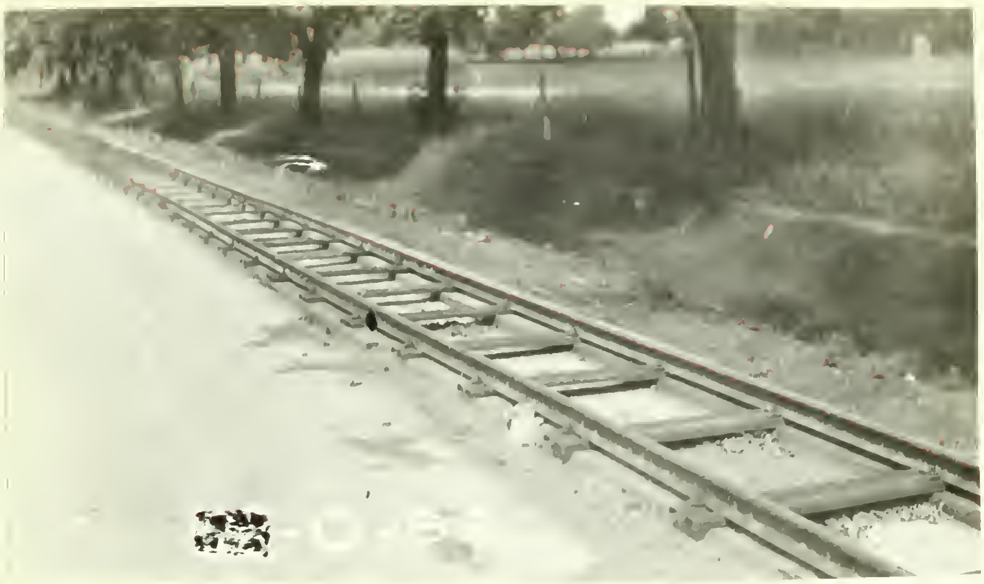
Track sufficiently heavy to carry the heavy rolling stock employed in the past was sometimes used, and gave good results as far as successful operation of the trains was concerned. The cost of laying and removing such track however, was excessive, and portability, so important in an operation of this kind, was sacrificed. Wooden ties were generally used in this type of track, but after the track had been relaid a few times the ties were so "spike-cut" as to render them useless. A comparison of fabricated and wood-tie track is included in the appendix.

WOODEN TIE TRACK

Prior to 1918, the corrugated type of tie bolted to the rail was almost universally used in light railway track. This tie was rolled by steel mills as a standard section, and was simply sawed off to the length desired for use in the track. As a rule the ties were short, with only a 2 inch or 3 inch projection beyond the rail. This resulted in "center-bound" track, because of the insufficient support afforded by the short projection of the tie. The ties were narrow, about 4 inches to $4\frac{1}{2}$ inches in width, and the open ends permitted the soil to flow when saturated with moisture. Sinking of the track resulted when the ground was at all soft, so it was necessary to place planks beneath the ties in order to secure sufficient bearing area. This was one of the big reasons why contractors in the past looked with disfavor upon the use of light railway haulage in highway construction.



SOIL FLOW CAUSED BY OPEN END TIES



PLANKS UNDER TRACK NECESSITATED BY INADEQUATE TIES

Bolting of the ties to the rail resulted in a track of but little rigidity. The rail on one side would frequently creep ahead of the rail on the other, so that it was quite difficult to replace a section or insert a switch. For this reason it was frequently necessary to saw one or more rails. The importance of rigidity in track construction has been pointed out by the Joint Committee on Track Stresses of the American Society of Civil Engineers and the American Railway Association, as a result of their researches in this subject. A rigid track distributes a load over a number of ties on each side of the one over which the load is actually placed. In a non-rigid track, however, the tie over which the load is actually placed is called upon to carry almost all of the load, inasmuch as it receives but little assistance from adjacent ties. In non-rigid track, therefore, heavy concentrated loads are liable to result in severe deformations.

The wide-spread application of light railway to military operations during the World War, resulted in the development of a pressed steel type of tie possessing much greater bearing area than the old type of corrugated tie. This type of tie has since been adopted in light railway track applied to highway construction, principally by The Lakewood Engineering Company, of Cleveland, Ohio. Instead of a projection beyond the rail of only 2 or 3 inches, the pressed steel tie projects some 7 or 8 inches. The ratio of tie projection to the gauge oftrack in the pressed steel tie type of track, is practically the same as in standard railroad construction. This type of track, therefore, is really standard railroad track in miniature. The old type of open end corrugated tie is usually 4 inches or 4½ inches wide and 32 inches long, whereas the pressed steel tie is 5½ inches wide and 42½ inches long. The pressed steel tie has a flange, approximately 1 inch deep, entirely around the sides and ends of the tie. Not only does this flange grip the ground so as to prevent shifting of the track, but it prevents soil flow and by its confining action increases the bearing power of the soil. The importance of this confining action is indicated by the investigations of the Joint Committee on Track Stresses, which emphasizes the importance of filling the space between ties with ballast up to the top of the tie so as to prevent flow of the ballast. Not only is the superficial bearing area of the pressed steel tie track considerably greater than that of the corrugated tie track, but the confining action of the flanges is such that the carrying capacity of the pressed steel

tie track is practically double that of the narrow, open and corrugated tie track. The rails are riveted to the ties in the pressed steel tie track instead of being bolted, thus providing greater rigidity and consequently lessened danger of local deformations over soft spots in the road bed. The use of a joint tie is another important feature of the pressed steel tie type of track, for it provides a supported joint instead of the suspended type common to the corrugated tie track. This joint tie lessens the danger of surface bends, while at the same time it is equipped with a special device which eliminates the necessity for splice plates and bolts. The pressed steel tie track shown in the photograph below has been in use two years in Illinois soil, and has been relaid perhaps a half dozen times or more.

In order to insure ease of portability and consequent low cost of laying and removing light railway track, investigation and experience indicates that the wheel loads to which the track is subjected should not exceed $1\frac{1}{2}$ tons. This limits the weight of four wheeled locomotives to 6 tons, or at the most 8 tons. If it is necessary to use heavier locomotives, they should be of the eight wheeled type. An eight wheeled locomotive weighing up to 12 tons, or at the most 16 tons, can be used on portable light railway track without harming the track. In order to retain the quality of portability in light railway track the rail should not exceed 20 pounds per yard in weight though sometimes 25 pound rail is used. The standard length of section equipped with 6 pressed steel ties riveted to the rail and 1 joint tie, as manufactured by the Lakewood Engineering Company, is 345 pounds. A mile of such track, containing 352 sections, will weigh 60.72 tons. Experience has shown that a 24-inch gauge of track gives sufficient stability to the rolling stock, which is specially designed with a low center of gravity, and does not require more room than is generally available on the shoulder of a road.

In laying light railway track the sections are placed on flat cars, and the laying of the track proceeds from the unloading point outward. Four men are generally required to handle a section of track, and 8 men in charge of a foreman can generally lay about one-half mile of track under normal conditions in 10 hours. At prevailing wages the cost of laying and removing a mile of light railway track has been found to be about $200.00, exclusive of freight and unloading.

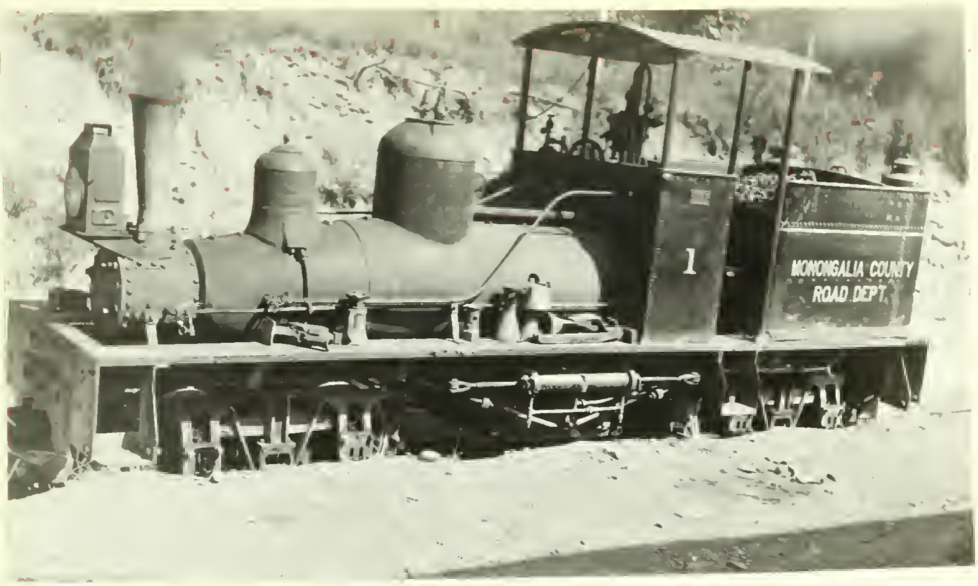
PRESSED STEEL-TIE TYPE OF TRACK

LAYING LIGHT RAILWAY TRACK

The type of locomotive commonly employed in light railway haulage on highway construction at the present time, is a four-wheeled gasolene machine weighing from 3 to 6 tons. Inasmuch as grades of 3 and 4 per cent are frequently encountered even in level country, the 6 ton locomotive is the type recommended for general use. Detailed specifications for a typical machine will be found in the appendix.

SIX-TON WHITCOMB GASOLENE LOCOMOTIVE

Very few suitable steam locomotives are in the market at the present time as most of them are single truck and are entirely too heavy for light portable track. The Davenport Locomotive Works, of Davenport, Iowa, manufacture a single-truck, 8-ton steam locomotive which seems to be well suited to light railway operation in highway construction. The Lima Locomotive Works, of Lima, Ohio, manufacture a double-truck, 10-ton locomotive of the Shay-geared type especially for road construction.



LIMA 10 TON, DOUBLE TRUCK STEAM LOCOMOTIVE

PLYMOUTH 6 TON GASOLENE LOCOMOTIVE

When light railways were first extensively used in highway construction, in 1919, a V shaped type of body containing separate compartments for sand, stone and cement was carried on a running gear. Since that time the batch box system has been developed, enabling 2 boxes to be carried per car. Two general types of batch boxes are on the market, namely the tip-over and the drop bottom type, either of which can be supplied with or without separate compartments for sand, stone and cement. The best practice favors the use of cement compartments, and some states will not permit cement to be dumped into the same compartment with sand and stone. The advantage of the tip-over type of box lies in the absence of movable parts or fastenings, while the disadvantage is the difficulty in tipping because of the lowering of the center of gravity as a smaller batch is used than that for which the box was designed. This latter objection has been overcome, however, by the use of adjustable trunnion plates, which enable the point of attachment of the lifting bail to be lowered as the center of gravity of the box is lowered. The best type of tip-over batch boxes are of steel construction with

adjustable trunnion plates and a separate cement compartment which can be entirely removed or moved toward one end or the other in accordance with varying ratios of sand and stone. The cement compartment should be provided with a lid, and should be raised from the bottom of the batch box so that rain penetrating the sand and stone will not moisten the cement. Complete drawings and specifications for one of the most widely used types of tip-over batch boxes will be found in the appendix.

BATCH-BOX SYSTEM OF LIGHT RAILWAY HAULAGE

Batch box cars are generally arranged to carry two boxes per car, as shown in the preceding photograph, when the size of batch does not exceed 5 bags. For a size of batch suitable for a 28-E paving mixer, only one box is carried per car. At the present time the Easton Car & Construction Company, of Easton, Penna. are manufacturing a car for carrying three batch boxes of the 4 bag type. Considerable difficulty is experienced, however, in swinging the middle batch box in and out of place. Considerable thought has been given to the manufacture of a double truck platform car for carrying 4 or more batches. To date, however, such a car has been found to cost more per batch than a single truck car, while the difficulty of handling the middle batch boxes is such as to discourage its use. A double truck car is easier on the track than the single truck type,and undoubtedly the double truck car, equipped perhaps with automatic couplers, will come into general use later on. A common type of double truck car used for general utility hauling is illustrated in the photograph on the following page.

When light railway haulage was first applied to highway construction the train speed was very low,due to the poor character of track used, and did not exceed 3 or 4 miles per hour. Under such conditions cars equipped with mild steel axles designed with an ordinary factor of safety, were found to be satisfactory and very little axle trouble occurred. With the introduction of the pressed steel tie type of track properly laid and maintained and with proper limits placed upon the weight of locomotives, operating speeds increased to as high as 20 and 25 miles per hour in some cases with an average of 8 to 10 miles. Under these conditions considerable trouble was encountered thru the breakage of mild steel axles, which, investigations by metallurgists, showed,was due to so-called fatigue of metal induced by rapid reversal of stress. It was found necessary, therefore,

to increase the factor of safety considerably, and to employ heat-treated, high-carbon steel axles. This is the type of construction used in the best cars at the present time.

When light railway haulage was first applied to highway construction, cars equipped with brass or bronze bearings were considered plenty good enough. The heavy locomotives used at that time possessed a hauling capacity more than sufficient to compensate for the increased rolling resistance resulting from the use of bearings of this type. With the advent of the modern improved type of track, permitting higher speeds, and recognition of the fact that wheel loads of locomotives should not exceed 1½ tons, the weight of locomotive was decreased to such an extent that it became necessary to reduce the rolling resistance of cars to a minimum. The caged-roller type of bearing, and in many cases high class bearings such as the Hyatt roller bearing were, therefore, adopted, and all the best cars at the present time are equipped with such bearings. Actual tests in the field by dynamometer have shown that whereas the rolling resistance of cars equipped with brass or bronze bearings vary from 30 up to 70 pounds per ton, the rolling resistance of cars equipped with caged roller bearings operating on a high carbon, heat-treated axle has not exceeded 10 pounds per ton. Spring draw bars and bumpers and spring pedestals characterize the modern light railway car, as compared to the old type. The appendix contains specifications of one of the most widely used types of batch box cars on the market today.

DOUBLE-TRUCK, GENERAL-UTILITY PLATFORM CAR

The indifferent success attending light railway haulage in highway construction previous to 1919, was largely due to failure to operate the railway on standard railroad principles. Very little attempt was made to deliver material at any predetermined rate to the concrete mixer, or to operate trains on a schedule. The result was an erratic and undependable supply of material, and the operation of trains in a "hit-or-miss", haphazard fashion. To operate trains on a light railway on a definite schedule was generally considered impossible or impractical, and with the frequent derailments caused by the make-shift character of equipment perhaps it was really so. Light railway operation under the severest conditions in military operations, however, has indicated the entire feasibility of running light railway equipment of proper design on definite schedule in

accordance with standard railroad principles.

The modern conception of light railway operation applied to highway construction is that a light railway is merely a commercial railway in miniature under intensive traffic, and that all problems peculiar to standard railroad practice apply with equal force to the operation of a light railway. The use of field telephones similar to those employed in military service in order to control the movement of trains, has even been contemplated on light railway operations applied to highway construction of large extent. Modern practice demands the use of equipment of the highest type, especially designed for the conditions peculiar to highway construction. Proper recognition of these fundamental factors has resulted in the large success which has attended the use of light railway haulage in highway construction during the past two years.

CHAPTER V.

TYPES OF LIGHT RAILWAY PLANTS.

Two types of light railway plant are commonly used in highway construction, the complete railway plant and the combined railway and motor truck plant. As its name indicates the complete railway plant affords complete transportation facilities for a job, while the combined railway and motor truck plant makes use of light railway in combination with motor trucks. The combined light railway and motor truck plant has been developed to overcome certain limitations to the use of the complete railway plant on some jobs. These limitations are topographic, geographic, size of job, financial ability of the contractor, and necessity for utilizing truck equipment on hand.

The topographic limitations are due, not so much to the steepness of any one grade, as to the distribution of grades. If only one steep grade is encountered it can generally be negotiated by means of the split train method, the booster locomotive method, the hoisting engine method, or the balanced train method, as described in the following chapter. If, however, a large number of quite widely separated steep grades occur, it becomes necessary to use a booster locomotive or one of the other methods at each grade. This would make the cost of a plant exceedingly high. By using only a mile and a half of track, in a manner described later on, the chances are that not more than one steep grade would be included in the railway portion of the haul. The investment in auxiliary grade climbing equipment would thus be reduced very considerably. Another topographic limitation to the use of a complete railway system on some jobs in hilly country, is due to the fact that the road frequently lies on a ridge, along which the grades are such as to make railway haul feasible. The unloading point, however, might be located in a valley, and the grade on a road leading from the unloading point might be excessively steep. In such a case the best method of operation would be to haul material in motor trucks from the unloading point to the road under construction, where it could be transferred to light railway cars for haul to the mixer.

The geographic limitation to the use of complete railway haulage on some jobs arises from the fact that the unloading point is sometimes located within the corporate limits of a city or town. It is generally impractical to lay light railway track on the streets leading from the unloading point to the road under construction. In such a case material is hauled in motor trucks from the unloading point to the job, where it is transferred to light railway cars for haul to the mixer.

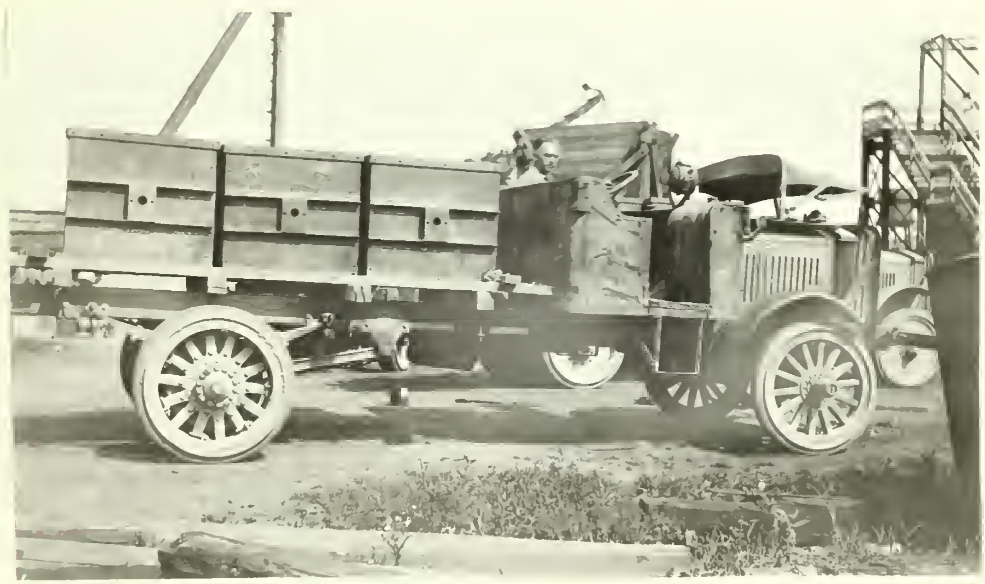
The purchase of a complete light railway road building plant naturally entails a considerable investment. In order to justify this investment and insure an adequate return on it, it is necessary that the job be of a certain minimum size. Of course if the contractor has a number of short jobs located quite closely together he has what practically amounts to one big job, and in such a case a complete railway plant can be economically justified on a smaller job than if only one were available. This question will be considered in detail in a later chapter, but suffice it here to say that on those jobs too small to justify a complete railway plant, a combination of light railway and motor trucks can be used. This combination gives the contractor practically all of the benefits of railway haulage, while at the same time it reduces his investment to a minimum.

Quite frequently a contractor is unable to make the proper financial arrangements for the purchase of a complete railway plant, even though he recognizes the economy and desirability of such a plant on a certain job. He might be in a position, however, to purchase about a mile and a half of track and a commensurate amount of rolling stock to use in conjunction with motor trucks, and thus secure the advantages of railway haulage.

Sometimes a contractor possesses a considerable amount of motor truck equipment and desires to make use of it, while at the same time he realizes the economy of railway haulage and desires to take advantage of it. In such a case a combined plant, using about a mile and a half of track, will permit the contractor to use his motor trucks and at the same time secure the advantages of railway haulage. Later on, if desired, he can easily add to his railway equipment, so as to secure a complete railway plant.

In certain sections of the country the average road job will be 5 or 6 miles long, or, if longer, the unloading points will be so located as to permit a 10 or 12 mile job to be handled by means of a few miles of track. Occasionally a 10 or 12 mile job will occur on which all the material must be hauled from one end. This would necessitate the use of 10 or 12 miles of track with a proportionate amount of rolling stock, in order to operate with a complete railway system. A contractor would probably find the purchase of so much equipment uneconomical for only one job, inasmuch as he would have but very little use for more than about one-third of it on the majority of his work. In such a case a few rented motor trucks used in conjunction with the railway equipment he already possesses, will enable him to secure the benefits of railway haul without a large additional investment in equipment.

The combined light railway and motor truck plan of operation has been developed in order to meet the limitations to the use of a complete railway plant on some jobs as set forth in the preceding paragraphs. In the combined light railway and motor truck plan of operation, batch boxes, each containing complete materials for one batch, are carried on motor trucks from the material yard to the road under construction and over the finished pavement as far as specifications permit.



BATCH BOXES CARRIED ON MOTOR TRUCKS.

Practically all state specifications permit traffic over the finished concrete road after the expiration of 21 days, and over the finished concrete base after the expiration of from 10 to 14 days. At the point where the concrete is not sufficiently cured to carry traffic, the loaded batch boxes are transferred from the trucks to light railway cars for haul pas~~sed~~t the uncured portion of the concrete to the mixer. It is obvious that this plan of operation requires only sufficient railway track to extend past the portion of the concrete not yet sufficiently cured to carry traffic. Each day as a section of concrete comes of proper age to carry traffic the transfer point can be advanced, and the track no longer needed in the rear can be picked up and relaid in advance of the mixer. A small crane or a light portable derrick with an 18 foot boom and about 2 ton capacity, is the best device for transferring batch boxes from truck to railway cars and vice versa. An "A" frame spanning the road equipped with a chain hoist and a trolley is sometimes used as a transfer device.

HAULING MATERIAL OVER CURED CONCRETE, COMBINED SYSTEM

TRANSFERRING BATCH BOXES FROM TRUCK TO CARS

The combined light railway and motor truck plant possesses practically all the advantages of a complete railway plant, such as elimination of wheeling and shoveling crew, reduction of labor in trimming and retrimming subgrade, elimination of lost and dirty material due to dumping on the subgrade, etc. Inasmuch as the motor trucks operate over an improved road and the remainder of the haul is over steel rails, delay due to rainy weather should be reduced to a minimum. The combined light railway and motor truck plan of operation, in common with the complete railway plan, permits the placing of concrete to begin at the point nearest the material yard. This eliminates delay in placing concrete,and permits the concreting and grading operations to be performed simultaneously. A large monthly estimate is thus insured early in the life of the job, and much needed working capital provided.

The railway portion of a combined light railway and motor truck haulage system, can easily be extended at any time so as to form a complete railway plant. Where a contractor desires to reduce his investment to a minimum it is recommended that motor trucks be rented,as a trucking company can afford to rent their trucks for less than the cost to a contractor of operating his own trucks. This is due to the fact that the trucking company operates all the year round, while the contractor operates only a part of the year and must absorb all the plant charges during the short road building season. While not quite so economical as a complete railway plant, where conditions permit this type to be used, the combined light railway and motor truck plant will effect very considerable economy over other methods of doing work where material is dumped on the subgrade or all of the haulage is performed over it. The combined light railway and motor truck plant offers to the contractor of limited means an opportunity to perform his work in an economical manner, and as he secures more capital he can add to his equipment, if desired, so as to eventually secure a complete railway plant. In operating a combined plant, practically all contractors rent the motor trucks.

Sometimes material is hauled in dump body trucks and is dumped near a small portable bin, into which it is handled by a crane equipped with a clam shell bucket , a bucket elevator, a portable bucket loader, or a short belt conveyor. Material is occasionally dumped on the finished pavement at the transfer point and shoveled into the batch boxes on the cars by hand, when, for some reason, a contractor does not desire to install a portable derrick or bin. This method is not economical and is only a make-shift. To supply a 14-E paving mixer a gang of from 8 to 10 shovelers are needed. The objection to the method of hauling material in bulk is the expensive rehandling equipment necessitated, and the cost of this rehandling. The best method of operating a combined plant is to load the batch boxes with complete materials at the material yard, haul them out to the road on motor trucks, and transfer to railway cars by means of a portable derrick. When batch box haulage is used it is unnecessary to haul cement bags out on the road and thus risk losing them, or bulk cement can be employed. The method of hauling material in bulk precludes the economy in handling cement which the batch box system insures. Another advantage of the batch box plan is the fact that a platform truck or a plain truck chassis equipped with a light wooden frame to hold the batch boxes,can be used. This reduces the cost of rental or purchase of trucks andincreases the number available for service. Dump body trucks can also be used to carry batch boxes if necessary. Many times it is practical to use trailers with the batch box system, and inasmuch as these trailers are double ended the problem of turning them is solved.

The complete railway plant, as previously mentioned, affords complete transportation facilities for a job. Detailed plans of operation for this type of plant,will be considered in a later chapter.

A problem quite frequently encountered in operating a light railway plant, is that of crossing the tracks of a standard gauge railway. Wherever it is possible to avoid crossing standard gauge tracks they should be avoided, but if necessary the crossing can be readily effected. Some railroads require a contractor to post watchmen about a half mile on each side of the crossing point, equipped with telephones, in order to notify the crossing watchman of the approach of trains. Other railroads do not require these precautions, and are content if a watchman is placed at the crossing itself. Needless to say the contractor should take every precaution to insure against an accident at the crossing point.

A number of different methods have been devised for carrying light railway track over standard gauge track. All these methods are alike in that no cutting of the rails in the standard gauge track is contemplated, nor would it be permitted by the railroad company. The type of crossing consists of a section of light railway track placed over the standard gauge track, in such a fashion that the light railway track can be removed after each passage of the train. The photographs below illustrate a number of light railway crossings.

LIGHT RAILWAY CROSSING HINGED HORIZONTALLY

LIGHT RAILWAY CROSSING HINGED VERTICALLY

COUNTERBALANCED LIGHT RAILWAY CROSSING HINGED VERTICALLY

The first of the foregoing illustrations shows a 15 foot section of light railway track hinged at one corner so as to permit it to be swung horizontally away from the standard gauge track after the passage of each train. The second illustration shows two $7\frac{1}{2}$ foot sections of track hinged so as to be swung back vertically away from the standard gauge track. The third illustration shows two $7\frac{1}{2}$ foot sections hinged vertically, and so equipped as to be swung back vertically by means of counterweights. These counterweights are attached to lines passing over sheaves on the "A" frame. The particular crossing illustrated in this photograph was at a point where the standard gauge railroad was located on a steep grade, and on a curve in a cut of considerable depth.

CHAPTER VI.

GRADES, SPEED AND SIZE OF TRAINS

The hauling capacity of a locomotive is a function of the weight on the driving wheels, and the character of metal in the wheel. With equal weight on the drivers and the same type of metal in the wheels, the hauling capacity of one type of locomotive is the same as that of another if sufficient engine power is provided to slip the driving wheels on dry rail. In full sized commercial locomotives some allowance must be made for the effect of the reciprocating parts on rod driven locomotives as compared to gear driven or electric driven machines, but for the small locomotives used on light railway the foregoing statement is true.

Tractive effort is the force exerted by the locomotive at the drivers, and is a function of the adhesion between the driving wheels and the rails. All of this force, however, is not available for pulling a train, as a certain amount of it is consumed in overcoming the rolling resistance of the locomotive itself. The force at the draw bar of the locomotive available for pulling a train, is equal to the tractive effort minus the rolling resistance of the locomotive itself. The engine power provided is, of course, partly consumed in overcoming friction within the mechanism of the locomotive, and in other losses.

The factor of adhesion between steel rails and steel driving wheels is generally taken at 25 per cent when the rail is dry, while the factor of adhesion between cast iron wheels with a chilled tread and a dry rail is generally taken at 20 per cent. When the rail is wet both of these factors are reduced considerably, but, on the other hand, the application of sand will serve to increase them up to a limit of approximately 40 and 35 per cent for steel and cast iron wheels, respectively.

The rolling resistance of a train is the force required to maintain a constant speed by overcoming the retarding influence of friction in the bearings, friction between wheels and rails, and all other forces tending to retard the movement of the train. The force required to accelerate a train must not only overcome the rolling resistance, but it must also overcome the inertia. The force employed in overcoming the inertia of a train is stored in the train in the form of kinetic energy, which later on tends to keep the train in motion when the speed is reduced. It is apparent, therefore, that greater force is required to accelerate a train than to keep it going after a start has once been made. The retarding influences of friction would in time consume the kinetic energy stored in a train, ed provid~~ing~~, it was operating on the level so that the force of gravity would not come into play, but brakes are provided in order to consume this kinetic energy thru the medium of friction to enable the train to be stopped wherever desired. In standard railroad practice where trains operate at a high rate of speed, the effect of atmospheric resistance must be taken into account. This factor can be neglected, however, in the small trains operated at the comparatively low rate of speed prevailing on light railway employed in highway construction.

The frictional resistance of bearings forms the greater part of the rolling resistance of a train, and this frictional resistance depends largely upon the type of bearing used. In standard railroad practice the rolling resistance of cars in good condition is generally about 5 or 6 pounds per ton, but the rolling resistance of light railway cars varies from 10 to 70 pounds per ton. The lower value is obtained when caged roller bearings and high carbon, heat-treated axles

are used, while values from 20 pounds up to 70 pounds prevail with brass or bronze bearings and mild steel axles. The importance of reducing rolling resistance to a minimum is apparent when we consider that a locomotive can pull practically three times as heavy a train on the level with a rolling resistance of 10 pounds per ton as it can pull with rolling resistance at 30 pounds per ton. The limited draw bar pull available in the small type of locomotive featured in modern light railway practice in order that wheel loads will not exceed $1\frac{1}{2}$ tons, makes reduction of rolling resistance of cars to a minimum doubly important.

The effect of grades is to increase the rolling resistance of a train 20 pounds per ton for each per cent of grade, and to decrease the draw bar pull of the locomotive 20 pounds per ton weight of the locomotive. This is due to the effect of gravity, and a proof of this phenomena can easily be effected by means of a diagram of forces. The application of this law can perhaps best be demonstated by means of an example.

A 6 ton locomotive having a weight of 12,000 pounds on its drivers and cast iron driving wheels with chilled treads, will have a draw bar pull of 2,400 pounds on the level. Such a locomotive is capable of pulling a train weighing 120 tons on the level, with a rolling resistance of 20 pounds per ton. Inasmuch as the draw bar pull of the locomotive is decreased 20 pounds for each ton of weight for each per cent of grade, the draw bar pull on a 1 per cent grade would be 2,280 pounds. The rolling resistance of a train, on the other hand, is increased 20 pounds per ton for each per cent of grade, making the rolling resistance 40 pounds per ton on a 1 per cent grade. The locomotive we have in mind, therefore, could pull a train weighing 57 tons on a 1 per cent grade. It is thus apparent that a 1 per cent grade will reduce the hauling capacity of a locomotive to less than half of its capacity on the level, when the rolling resistance of the train on the level is 20 pounds per ton. If the rolling resistance on the level is only 10 pounds per ton, the hauling capacity of a locomotive would be reduced by one-half on a grade of only one-half of one per cent. The serious effect of grades on the size of a train is thus clearly apparent, and shows why standard railroad practice generally sets a maximum of about three-tenths of one per cent to its main line grade. The lower the rolling resistance of the cars, the greater is the influence exerted by grades on the size of train.

The hauling capacity of any locomotive can easily be computed in the manner shown above, but sometimes a formula showing the relations between the speed and hauling capacity is convenient. For sake of illustration a formula of this kind, applicable to a typical 6 ton gasolene locomotive widely employed in light railway haulage in highway construction, will be derived. This locomotive is equipped with a 50 horse power engine and can exert a draw bar pull on the level of 2,400 pounds at 5 miles per hour and 1200 pounds at 10 miles per hour. The adhesion of the driving wheels to the rail is 20 per cent under normal condition. The rolling resistance of the train will be assumed to be 20 pounds per ton.

Let R represent train resistance on the level
Let W " weight of train in tons
Let S " speed in miles per hour
Let L " distance traveled in feet per minute
Let G " per cent of grade
Let V " vertical distance lifted in feet per minute
Let H' " engine horse power
Let H " draw bar horse power
Let E " ratio of draw bar horse power to engine horse power
Let D " draw bar pull in pounds

$$L = \frac{5280\ S}{60} = 88\ S$$

$$\frac{D\ L}{33000} = E\ H' = \frac{D\ 88\ S}{33000} = \frac{D\ S}{375}$$

$$H = E\ H'$$

When $S = 10$, $D = 1200$, therefore $E = 0.64$ and $H = 0.64\ H'$

$H' = 50$, therefore $H = 32$

$R = 20\ W \qquad V = G\ L = 88\ G\ S$

$$H = \frac{R\ L + 2000\ (W + 6)\ V}{33000} = \frac{20\ W\ 88\ S + 2000\ (W + 6)\ 88\ S\ G}{33000} =$$

$$\frac{S\ [W + 100\ G\ (W + 6)]}{18.75} = 32$$

$$S = \frac{600}{W + 100\ G\ (W + 6)}, \quad W = \frac{600\ (1 - G\ S)}{S\ (1 + 100\ G)}, \quad G = \frac{600 - W\ S}{100\ S\ (W + 6)}$$

Experience has shown that the performance of locomotives in the field is entirely in accordance with the expressions for S, W, and G shown above. In applying this formula, however, in which the hauling capacity of the locomotive varies inversely with the speed, it must not be forgotten that the limiting factor at all times is the adhesion between the driving wheels and the rails. For instance, if we assume a grade of 4 per cent and a speed of 2 miles per hour, we get a value for W of 55.2 tons. Inasmuch as the rolling resistance of the train is increased 20 pounds per ton for each per cent of grade, the draw bar pull necessary to haul a train of this weight up a 4 per cent grade is 5,520 pounds. We have previously seen, however, that the maximum draw bar pull which a 6 ton locomotive equipped with cast iron drivers can exert is 20 per cent of its weight, or 2,400 pounds. It is apparent, therefore, that a locomotive of this type cannot haul a 55 ton train up a 4 per cent grade. The discrepancy arises from the fact that the formula does not apply for speeds lower than 5 miles per hour, because at lower speeds the pull which the engine of the locomotive can develop exceeds the adhesion of the locomotive to the rail. In other words the draw bar pull will not be increased by operation at a speed lower than 5 miles per hour, as the formula indicates, on account of the limiting factor of the adhesion of the driving wheels to the rail. It is entirely possible to operate the locomotive at speeds much lower than 5 miles per hour, but the draw bar pull will not vary inversely with the speed, as indicated by the formula, when the rate is less than 5 miles per hour. Of course if the rails are sanded or steel driving wheels are used on the locomotive, the adhesion will be increased to such an extent that the draw bar pull will vary inversely with the speed, as shown by the formula, at rates lower than 5 miles per hour. It is not wise, however, to assume conditions other than those of normal dry rail. The limiting factor to the hauling power of any locomotive is the adhesion between the driving wheels and the rail, and engine power in excess of that required to spin the driving wheels under normal conditions will not increase the hauling power.

A 3 ton gasolene locomotive, equipped with cast iron driving wheels, of the type commonly used in highway construction, can exert a draw bar pull on the level of 1,200 pounds at 5 miles per hour and 600 pounds at 10 miles per hour under normal conditions. The formula for the hauling capacity of this locomotive is

$$W = \frac{300\ (1 - G\ S)}{S\ (1 + 100\ G)}.$$

If steel driving wheels are used, in place of cast iron wheels with chilled tread, the factor of adhesion between the drivers and the rails will be increased to 25 per cent. A 6 ton locomotive with steel drivers can exert a draw bar pull on the level of 3,000 pounds at 5 miles per hour, and 1,500 pounds at 10 miles per hour. The formula for hauling capacity for a 6-ton locomotive with steel drivers will be $W = \frac{750\ (1 - G\ S)}{S\ (1 + 100\ G)}$. $W = \frac{375\ (1 - G\ S)}{S\ (1 + 100\ G)}$ is the expression of hauling capacity of a 3 ton locomotive equipped with steel drivers. The principal advantage of steel driving wheels is not the increased draw bar pull on the level resulting therefrom, but the increased hauling capacity on grades.

The effect of gravity is to retard a train ascending a grade, and to reduce the hauling power of the locomotive. On descending grades, however, gravity tends to increase the speed of the train, and to decrease the draw bar pull required to overcome the rolling resistance of the train. When the grade is sufficiently steep the draw bar pull required to overcome the rolling resistance of the train becomes negative, so that brakes must be provided to retard the train. The effect of gravity on a descending grade is to exert a pull of 20 pounds per ton weight of train and locomotive for each per cent of grade. On a 1 per cent descending grade, therefore, the effect of gravity is just sufficient to overcome the rolling resistance of a train of 20 pounds per ton. On descending grades a high rolling resistance is an advantage, for it assists in retarding the train and thus makes control by means of brakes easier.

In standard railroad practice, grades known as velocity grades are frequently used. These grades consist of opposing descending and ascending grades. On the descending grade the train is permitted to run without the application of brakes, and the kinetic energy attained is utilized to ascend the opposing grade. In this manner the force of gravity is called into play so as to reduce fuel consumption. In light railway operation as applied to highway construction, however, velocity grades are generally not practical, because of the light equipment and the temporary character of the track.

The effect of a descending grade on the speed of a train can be demonstrated in the following manner:

Let V	represent	the velocity in feet per second
Let KE	"	the kinetic energy of a train at V feet per second
Let S	"	speed in miles per hour
Let g	"	the acceleration of gravity
Let H	"	height in feet to which KE will lift train
Let W	"	weight of locomotive and train in pounds
Let G	"	per cent of grade
Let L	"	horizontal distance in feet
Let R	"	rolling resistance at 20 pounds per ton $= \frac{W}{100}$

$$H = \frac{V^2}{2\,g}, \quad V = 1.467\ S, \quad H = 0.03344\ S^2, \quad S = 5.47\sqrt{H}$$

$$H = G\ L, \quad V^2 = 2\ g\ H = 2\ g\ G\ L$$

$KE = 1/2\ M\ V^2 = 1/2\ \frac{W}{g}\ 2\ g\ G\ L = W\ G\ L$ = the kinetic energy of the train provid~~ing~~ed the rolling resistance were zero. The retarding action due to rolling resistance, however, is $\frac{W\ L}{100}$.

$$W\ G\ L - \frac{W\ L}{100} = 1/2\ M\ V^2 = \frac{W\ V^2}{2\ g} = \text{actual KE of train.}$$

$$G\ L - \frac{L}{100} = \frac{V^2}{2\ g}, \qquad 100\ G\ L - L = 1.55\ V^2$$

$$V^2 = \frac{100\ G\ L - L}{1.55}, \qquad V = \sqrt{\frac{L\ (100\ G - 1)}{1.55}}, \qquad V^2 = 2.15\ S^2$$

$$S^2 = \frac{L\ (100\ G - 1)}{3.31}, \qquad S = \sqrt{\frac{L\ (100\ G - 1)}{3.31}}$$

S represents speed due to the effect of gravity, assuming the train starts from the top at a stand still. If the train approaches the top of the grade at a certain speed, this speed should be added to that due to gravity in order to obtain the final speed at the bottom of the grade.

A train with a rolling resistance of 20 pounds per ton, will attain a speed due to gravity of 25 miles per hour at the bottom of 500 feet of 5 per cent grade. If the train resistance is less than 20 pounds per ton, the speed attained would be even greater than 25 miles per hour. While speeds of 20 and 25 miles per hour are occasionally attained on light railway used in highway construction, it is not considered wise to operate at a rate of speed exceeding 10 or 15 miles per hour.

The braking power of a locomotive depends upon the adhesion of the driving wheels to the rail, in the same manner that the hauling power depends upon this factor. Theoretically, therefore, a locomotive can control the same weight of train on a descending grade, by means of its brakes, that it can haul up an ascending grade. An overloaded locomotive on an ascending grade will stop of its own accord, however, while an overloaded locomotive on a descending grade, if the cars are not equipped with brakes, cannot be stopped. Descending grades are a greater source of danger and must be more carefully watched, than ascending grades. Fortunately it is unnecessary to depend upon the brakes on the locomotive alone, for brakes can also be placed on the cars. On a light railway train, however, automatic brakes are too expensive, and it is not practical to apply brakes on more than three cars, one next to the locomotive and two at the end of the train, unless additional men are provided for this purpose. As a rule but one train man is provided, and he rides between the two last cars in order to apply the brakes on them. The brakes on the car next to the locomotive can be applied by the locomotive operator. The braking power of cars is computed in the same manner as that of the locomotive, by multiplying the weight of the car by the factor of adhesion between the wheels and the rails.

As mentioned in the foregoing paragraph speeds of 20 and 25 miles per hour are sometimes attained in light railway operation, but the average operating speed is from 8 to 10 miles per hour. Experience indicates, however, that an average speed of 6 miles per hour is the proper speed to use in proportioning the amount of rolling stock required. In rolling country where the ascending and descending grades balance one another fairly well in length and degree, the speed of operation is almost as great as it is in level country. This is due to the fact that descending grades compensate, to a certain extent, for the ascending grades. Due to the necessity of applying brakes in order to keep the speed within safe limits, the descending grades do not entirely compensate for the ascending grades. In most cases, however, an average speed of 6 miles per hour can be used as a basis for proportioning the amount of rolling stock required in hilly country as well as in level country.

If desired, the average speed of operation in hilly country can be computed from a profile by means of the formula derived on page 39. This formula enables the speed of train to be computed on grades, while on level sections the speed can be assumed at 10 miles per hour. On down grades, also, a speed of 10 miles per hour can be used. On an ascending grade the speed derived from the formula will be the speed at the top of the grade, and the mean speed for the entire grade can be obtained by averaging the speed at the top and the speed at which the train approached the bottom. The mean speed of a down grade can be obtained by averaging the speed at which the train approached the top, and the assumed speed of 10 miles per hour at the bottom. While this is not strictly correct, it is accurate enough for all practical purposes. The average operating speed for the entire job can then be obtained by multiplying the length of each grade and level stretch by its average speed, and dividing the sum of these products by the total length of the road. Except where ascending or descending grades predominate, it is seldom necessary to go to the refinement of computing the weighted mean speed from the profile.

Specifications generally require concrete to be mixed a certain minimum time, generally one minute. Under such conditions a 14-E paving mixer should average about 30 batches per hour, and a 21-E paving mixer about the same. A 28-E paving mixer should produce about 24 batches per hour. The object of light railway haulage, therefore, is not to deliver the maximum amount of material possible between two points, but rather to so coordinate haulage operations as to supply the mixer at a predetermined rate of about 30 batches per hour. The size of train should be such as to supply the mixer at the predetermined rate during the interval between arrival of trains, providing topographic conditions are such as to permit this to be done. In level country it is possible to haul trains of 30 to 40 loaded cars, but unless the length of haul is such that the intervals between the arrival of trains at the mixer are sufficiently great to enable the mixer to consume the amount of material carried by such a train, a train of this size would not be economical. In other words the size of trains on any particular job is not always determined by topographic conditions, and consequently the hauling capacity of the locomotive, but often by the length of time required per round trip between mixer and material yard. The time element as well as the topographic element must be considered in determining the size of trains.

Suppose, for instance, that operations were being carried on in level country on a 2 mile haul, and that a 6 ton locomotive could haul a 40 car train. At a speed of 6 miles per hour, the locomotive would make a round trip in 40 minutes. Allowing 5 minutes for switching trains at the mixer and the same amount of time at the material yard, a total of 50 minutes would be required per round trip. Three trains would be necessary, 1 at the mixer, 1 at the material yard, and 1 in transit.

A 40 car train would carry 80 batches, or a sufficient amount of material to supply the mixer for 160 minutes at the rate of 30 batches per hour. On the round trip of 4 miles the locomotive can arrive at the mixer at 50 minute intervals, and during this interval the mixer would consume only about 25 batches. A train of 12 or 13 cars, therefore, would be sufficiently large to supply the mixer at the predetermined rate. If 40 car trains were used a total of 120 cars and 240 batch boxes would be needed, while 3 trains of 13 cars each would make a total of only 39 cars and 78 batch boxes. It is obvious, therefore, that in this case it would not be economical to load the locomotive up to its maximum hauling capacity. The point it is desired to emphasize is that in level country the size of train is frequently determined by the length of running time between the mixer and the material yard, because the rate of operation of the mixer is limited by specifications. The problem of operating a light railway in highway construction is not merely one of transporting a maximum amount of material between two points, but rather one of so coordinating the transportation efforts as to supply the mixer with the maximum amount of material which specifications permit it to consume.

TWENTY-FIVE CAR TRAIN IN ARIZONA

THREE CAR TRAIN ON 8.2 PER CENT GRADE IN PENNSYLVANIA

The preceding photographs illustrate very clearly the effect of grades on the size of trains. The locomotives employed in both of these operations are 6 ton gasolene, friction drive machines, of equal hauling capacity.

In level country the length of running time between the mixer and the material yard frequently determines the size of train, but in hilly country, of course, the size of train is limited by the grades. It is necessary, therefore, to run trains at more frequent intervals in hilly country than in level country. The influence which grades exert upon light railway haulage, however, is not so much due to the actual steepness of the grade, as it is to their number and distribution. If only one steep grade exists on a job it can be surmounted by means of a booster locomotive, or one of the other methods described in the following paragraphs. If the steep grades are many in number, or so distributed that a booster locomotive or some other method is required at each grade, the question of grades becomes serious because of the increased amount of equipment required.

Several methods of negotiating steep grades are in general use at the present time. The principal methods are known as the booster method, the split train method, the hoisting engine method, and the balanced train method.

The booster method consists of using an extra locomotive to push or pull a train up a steep grade. By this method a train of approximately twice the weight that a single locomotive can handle, can be taken up a grade. Instead of using an extra locomotive, other motive power such as a motor truck, a tractor, or even a team of horses is sometimes used to pull a train up a grade. Auxiliary motive power of this kind is generally used where but one steep grade must be considered.

BOOSTER LOCOMOTIVE METHOD OF NEGOTIATING STEEP GRADES

Perhaps the most popular method of surmounting steep grades, is by what is known as the split train method. In this method the locomotive is placed in the middle, and half of the train taken up the grade at a time. The split train method is especially adapted to a job containing but one steep grade, and in such a case it is generally more economical than the booster locomotive method. A certain amount of time is lost, of course, by the split train method, and where a number of grades exist the running time is sometimes so increased that it is questionable

whether to purchase the additional cars and locomotive needed to properly supply the mixer or to purchase booster locomotives. Conditions surrounding each job must govern in such a case.

MOTOR TRUCKS HAULING TRAIN UP STEEP GRADE

The time required to negotiate a grade by the split train method can be estimated in the following manner: Assume a 6 per cent grade 1,000 feet long. Under normal conditions, a 6 ton locomotive equipped with steel driving wheels will pull a 5 car train carrying 10 batches up such a grade. Assume that the other grades are such that an 8 car train can be used. By placing the locomotive in the center of the train, 4 cars can be taken up the 6 per cent grade at a time. The weight of a 4 car train, each car carrying 2 - 4 bag batches of material, is about 13-1/2 tons, and a 6 ton locomotive will haul such a train up a 6 per cent grade at a speed of 5.5 miles per hour or 484 feet per minute. Assuming the train stops 100 feet from the bottom of the grade and runs the same distance beyond the top, the locomotive should cover the distance of 1,200 feet in about 2.5 minutes. Coming down the grade the locomotive will average about 10 miles per hour, so that 1.5 minutes are needed for this purpose. Allowing 1/2 minute at the bottom of the grade to set brakes on cars and to uncouple and the same amount of time at the top of the grade, a total of 2 minutes will be required for this purpose. Adding the time required to run up and down the grade, gives a total of 8.5 minutes which are required to negotiate this grade by the split train method. At a speed of 6 miles per hour, a train will travel 1 mile in 10 minutes. The extra time consumed on this grade due to splitting the train is 6 minutes, so that the effect of this grade is the same as if the haul were increased 0.6 of a mile. If a number of grades are encountered, it is obvious that the running time of trains might be so increased as to necessitate additional equipment in order to properly supply the mixer.

The hoisting method of steep grade operation, consists of placing a hoisting engine at the top of the grade and attaching a line to the train. The pull which can be obtained from the hoisting engine depends upon the side of the engine, and upon the size and speed of the drum. When a hoisting engine is used to assist a train up a steep grade, it should be set at one side of the road and the cable passed around a sheave in the center of the track. Empty trains on the

way down grade, pull the cable to the bottom in order that it may be in readiness for the next ascending train. The hoisting engine method is limited by the line capacity of the drum, and by curves in the track.

The balanced train method utilizes the weight of the empty descending train to assist the loaded train up the grade, by means of a cable passed around sheaves at the top. Double track is generally used in this method, but a single track with a passing siding half way up can be used if the sheaves at the top are both placed outside of the rails. In operation the cable is attached to the rear car of the empty train at the top of the grade, and to the loaded train at the bottom of the grade. The operator on the empty train allows his train to descend without the application of brakes, so as to give the force of gravity full play. In this method of operation, the loaded and empty trains alternately occupy right and left hand tracks or passing siding. Assume a 6 ton locomotive with steel wheels is to negotiate a 6 per cent grade, with an 8 car train. Such a train, each car carrying 2 - 4 bag batches of material, would weigh about 27.2 tons. On a 6 per cent grade the locomotive could exert a draw bar pull of 2,280 pounds, while a train of this weight, with a rolling resistance of 20 pounds per ton on the level, would require a pull of 3,808 pounds. An additional pull of 1,528 pounds over the draw bar pull must be provided, if the train is to be hauled up the grade in question. An empty car carrying 2 steel batch boxes will weigh 2,000 pounds, so that the empty train with the locomotive will weigh 14 tons. The influence of gravity will cause a pull of 20 pounds per ton for each per cent of grade, or 120 pounds per ton on a 6 per cent grade. Subtracting the rolling resistance of 20 pounds per ton, leaves a net pull of 100 pounds due to gravity. The pull delivered by the 14 ton descending train, therefore, would equal 1,400 pounds. Inasmuch as an additional pull of 1,528 pounds is required, the weight of the descending train is hardly sufficient. By the use of sand, however, this grade could be surmounted very nicely. If the rolling resistance were only 10 pounds per ton the descending train would furnish a 1,540 pound pull, while the additional pull needed by the ascending train would be only 1,256 pounds.

Sometimes it is possible to so arrange passing sidings and schedules, that trains will meet either at the top or the bottom of the grade. In such a case the locomotive on the empty train can be detached, and utilized as a booster. The delay would not be quite as great as that required by the split train method, but the location of the passing siding at the top or bottom of the trade might cause a serious derangement of the operating schedule. At times, however, this method can be employed, and it is well to keep it in mind.

Considerable thought and study has been given to the problem of developing a rack and pinion method for use on steep grades. The idea is to bolt the rack to the track in sections, and to place a pinion on an axle of the locomotive so that it would mesh with the rack in somewhat the same manner as in the cog wheel system. The difficulty of securing proper meshing between the rack and pinion is such, that to date this method has not proven practical.

Whenever possible it is preferable to pull a train by means of the locomotive, rather than to push it. Pushing a train causes the car wheels to jam against the rail, and not only increases the rolling resistance but increases the possibility of derailment. The increased rolling resistance caused by pushing light railway trains, is such as to reduce the capacity of the locomotive very considerably.

The 6 ton gasolene locomotive is the type best adapted to light railway

operation in highway construction at the present time, inasmuch as the wheel loads to not exceed 1-1/2 tons and the draw bar pull is sufficient to enable a fair size train to be used. In level country the 3 or 4 ton locomotive is frequently used, but even here opinion is gaining ground that the 6 ton machine is the best type. A 10 ton geared locomotive on double trucks suitable for highway construction, illustrated on page 27, is manufactured by the Lima Locomotive Works, of Lima, Ohio The difficulty of designing a small machine of this type, so the manufacturers claim, is such that the available draw bar pull is not commensurate with the weight of the machine. The draw bar pull on this locomotive is only 3,400 pounds, instead of the 5,000 pounds which a machine of this weight, equipped with steel wheels, should deliver. This particular locomotive does not possess sufficient engine power to develop the draw bar pull which its weight would enable it to deliver, and obviously it is not as efficient a unit as a 6 ton locomotive which utilizes all of its weight in pulling a train. The additional weight in an underpowered locomotive is of advantage only for braking purposes.

There is urgent need at the present time for a 10 or 12 ton double truck gasolene locomotive, designed with a low center of gravity and a short wheel base. No such machine is on the market, in fact there are really no satisfactory locomotives exceeding 6 tons in weight available for light railway operation in highway construction today. Experience indicates that gasolene is the best fuel for light railway operation in highway construction.

Three ton machines, as a rule, are not used on grades exceeding 4 per cent, while 6 ton locomotives are in successful operation in the State of Pennsylvania on grades up to 8 per cent. The photograph on page 43 shows a 6 ton locomotive hauling a 3 car train up an 8.2 per cent grade, each car carrying 2 - 4 bag batches of material for a 1-2-3 concrete. The question of limiting grades is not one of the maximum grade which a locomotive can climb, but one which it can climb while pulling a train of at least 3 cars. Theoretically a locomotive can climb a 20 per cent grade on dry rail, but this is of no practical interest to the contractor for he is concerned only in the size of train which a locomotive can handle on a given grade. Very seldom are grades in excess of 10 per cent permitted on any road which is to be improved with a so-called permanent pavement, and if steeper grades do occur they are generally short and can be handled by one of the methods previously described. Experience during the past two years indicates that light railway haulage can be economically employed, on any grades which are likely to be encountered on roads important enough to be improved with a pavement involving the use of concrete.

CHAPTER VII.

TRAIN SCHEDULES AND LOCATIONS OF SIDINGS.

It has previously been pointed out that one of the reasons for the indifferent success which attended the early efforts to apply light railway haulage to highway construction, was the lack of proper train schedules and failure to operate trains in a systematic manner. In order properly to operate a light railway system so as to supply material to the mixer at the required rate, it is necessary that the trains be operated on regular schedule. Each train should be given a number, and the operator impressed with the fact that he is to leave the material yard at such and such a time, to meet other trains at passing sidings at such and such a time, and to arrive at and leave the mixer at a certain time. A time schedule should be computed, and should be changed from time to time as the length of the haul necessitates. In order to assist in maintaining the schedule and to insure that help is speedily forthcoming in case of trouble, field telephones similar to those employed by the United States Army can be used. These phones are not very expensive, and they can be attached, in many cases, to wire fences along the way. On a big job these telephones could be used to control the movement of trains. While such an arrangement might seem elaborate at the present time, refinements of this character will come into more general use as the value of, and necessity for, good organization is more fully realized.

Schedules can be computed and used in either tabular or graphical form. The computation of a tabular schedule, from which a graphical schedule can be constructed, is shown below. The length of haul from the material yard to the mixer is assumed to be 4 miles, and the speed of the train 6 miles per hour. An allowance of 5 minutes for lost time on switches is made, though the rate of operation, 6 miles per hour, is generally sufficiently low to provide for this feature. An allowance of 5 minutes for switching trains at the mixer and the same amount of time at the material yard, is made. An 8-car, 16-batch train, is assumed, with the mixer operating at 30 batches per hour.

Train number	Arrive at yard	Leave Yard	Arrive at mixer	Leave Mixer	Arrive at yard
1	7:10	7:15	8:00	8:05	8:50
2	7:42	7:47	8:32	8:37	9:22
3	8:14	8:19	9:04	9:09	9:54
1	8:46	8:51	9:36	9:41	10:26

The schedule shows that train #1 arrives at the yard at 8:50, practically in time to take the place of what would have been train #4. Consequently on this particular job, 3 locomotives would be sufficient. Inasmuch as one train is left at the mixer while another is at the material yard and still another is attached to each locomotive, it is apparent that 5 trains of 8 cars each are required or a total of 40 cars and 80 batch boxes. Not only does this schedule indicate the time at which trains are to leave and arrive at various points, but it also indicates the amount of rolling stock required.

A short-cut method of determining the amount of rolling stock required consists of computing the round-trip time, and consequently the number of round trips per day. For instance, in the foregoing example a 4-mile haul is assumed at

6 miles per hour, with a 5-minute delay on switches, at the mixer, and at the material yard. The time required per round trip is 100 minutes, enabling a locomotive to make 6 round trips per 10-hour day. Each car carries 2 batches, so that 6 train loads of 8 cars each amount to 96 batches. Three locomotives, therefore, could deliver approximately 300 batches to the mixer, and by speeding up a trifle they could easily deliver 300 batches. The determination of the number of trains and cars required, is effected as in the previous method.

A time schedule, similar to the one shown on the preceding page, should be tabulated for the entire day. As the length of haul increases and the location of the sidings are changed, the time schedule should be properly modified.

In order to maintain train schedules it is necessary that passing sidings be located at the correct places, for if this is not done considerable time will be lost by trains waiting for each other. In the past improper attention has been paid to this feature of light railway operation, or if the sidings were correctly located at first they were not changed as the length of haul and the number of trains changed. The difficulty of changing siding locations with the make-shift type of track employed in the past, was no doubt responsible to a large degree for neglect of this important feature. The track in use at the present time is manufactured especially for light railway operation in highway construction, and is so designed as to permit of easy and rapid changing of passing sidings.

As the length of haul from the material yard to the mixer varies, it is necessary also to vary the number of trains in order to properly and economically supply the mixer. The locations of passing sidings must accordingly be changed from time to time. It is generally cheaper to change the location of a siding a quarter of a mile, than it is to allow the delay caused by the improper location to increase the running time of trains so that the required number of batches can not be delivered to the mixer. Of course, it is frequently impractical to locate sidings exactly where the train schedules require them to be because of narrow shoulders, but this can often be easily and cheaply corrected by means of a small amount of cribbing. In any event an attempt should be made to approximate the correct location as closely as possible. As a rule no movement of a siding of much less than a quarter of a mile is necessary or justified.

Steep grades are sometimes surmounted by placing passing sidings at the top or bottom, and uncoupling the locomotive from the empty train to assist the loaded train up a grade. This practice will occasionally avoid the purchase of additional motive power and in such a case might be justified, even though the location is not the correct one according to the schedule. If locating sidings at the top or bottom of a grade should so derange the train schedule as to reduce the output of the mixer, the question of whether it is less expensive to permit this or to purchase a booster locomotive can only be decided after proper consideration of all factors peculiar to the job.

Perhaps the best method of determining the location of passing sidings is the graphical method, shown in the accompanying graphs. The data on these prints apply to a two mixer plant supplied from one material yard, operating on what is known as a balanced haul. The time of leaving the material yard, arriving at the mixer, etc. is determined from a schedule such as that shown on page 48. The length of haul varies from 2 miles to 6 miles, and the locations of passing sidings are determined by the intersection of time curves for the various trains.

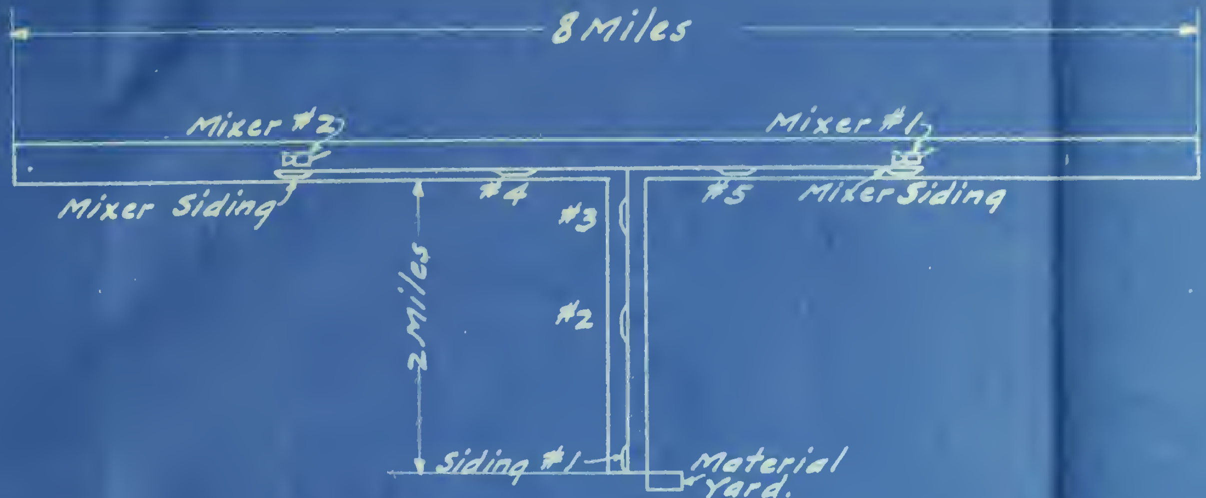
Graph #1, which applies when both mixers are at the 4 mile point, indi-

cates that returning train #1, serving mixer #1, encounters outgoing train #2, serving mixer #1, at a point about 2-5/8 miles from the material yard. Theoretically train #1, serving mixer #1, encounters train #1, serving mixer #2, at a point about 3-3/8 miles from the material yard, but inasmuch as the trains serving each mixer branch off at the 2 mile point this meeting in reality never occurs. Further on we see that train #1, serving mixer #1, encounters train #2, serving mixer #2, train #3, serving mixer #1, and train #3, serving mixer #2, at points approximately 1-3/4 miles, 1 mile, and 1/4 mile from the material yard respectively. At each of these points a passing siding is required, though the 1/4 mile siding is so close to the material yard that the siding at the material yard will probably suffice. Proceeding in a similar manner we find that with mixer #1 at the 6 mile point and mixer #2 at the 2 mile point, and with mixer #1 at the 5 mile point and mixer #2 at the 3 mile point, that additional sidings, or sidings at different locations, are required.

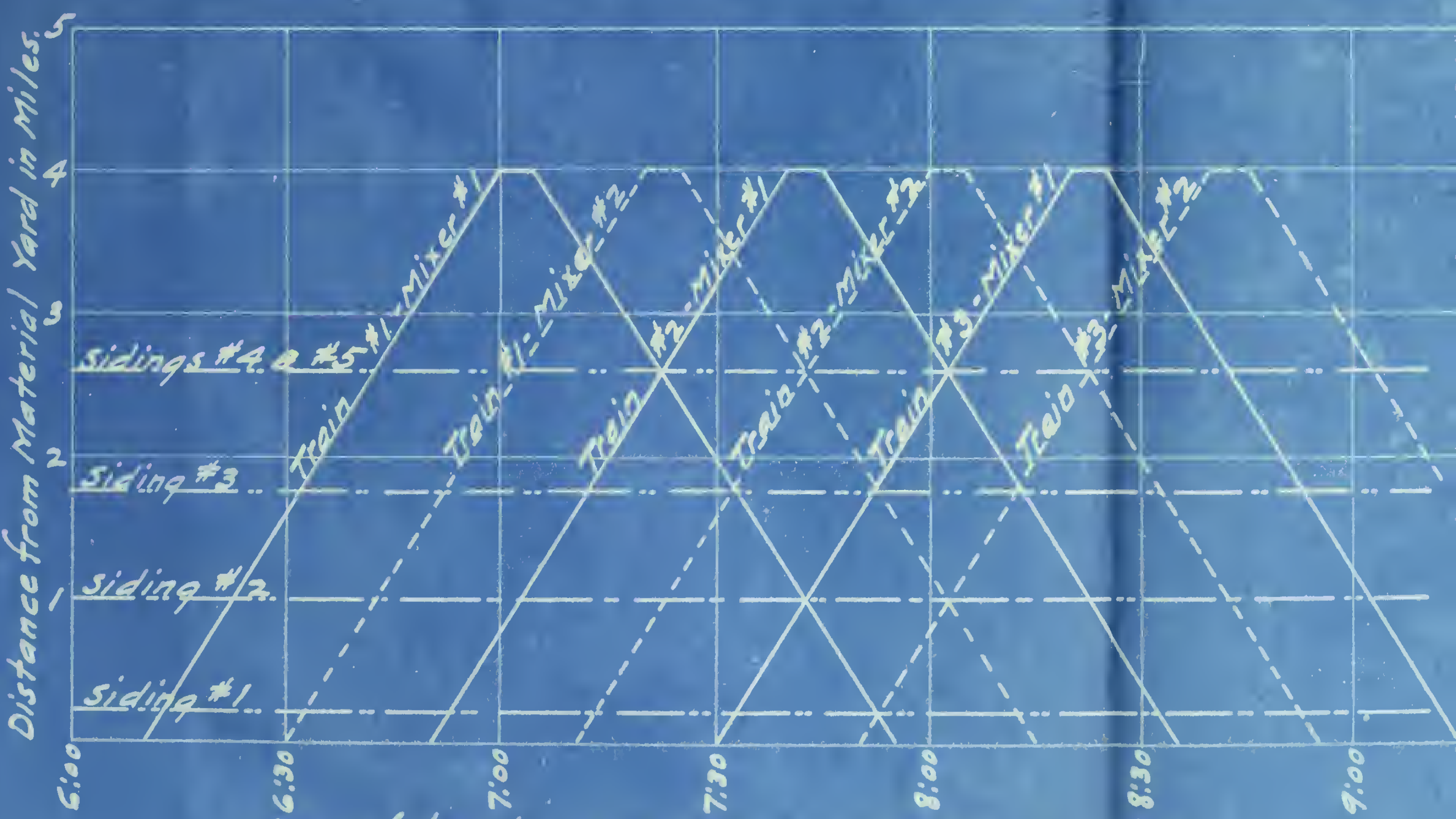
When two mixers are supplied from one material yard located some distance from the road under construction, the small changes in siding location required on the "dead haul" road need not generally be made. As a rule if the sidings along the "dead haul" road are located at the proper points for serving the mixers at the points of average haul, these locations are sufficiently correct for the other hauls involved. The sidings along the road under construction, however, should be changed from time to time, as occasion demands. As a rule sidings must be placed approximately a mile apart on a light railway line serving one mixer, with a passing siding at the mixer itself. When two mixers are supplied by one line of track, as on a road leading from the material yard to the road under construction, approximately twice as many sidings are needed as when but one mixer is used.

The application of the method of locating sidings described in the foregoing in case only one mixer is to be supplied from the material yard, is a simple matter. A preliminary study should be made to determine the proper location of sidings for the entire job, with the haul varying by 1 mile intervals from the minimum to the maximum. As the haul from the material yard to the mixer changes, sidings can be shifted accordingly to the points previously determined.

Practical common sense must always be used in applying this method of siding location, for it is apparent that a change in the size of trains or the speed of operation will necessitate corresponding changes in the location of sidings. A study of the passing siding problem in the manner indicated in the foregoing, however, should do much to eliminate haphazard operation of trains and to insure the maintenance of proper schedules.

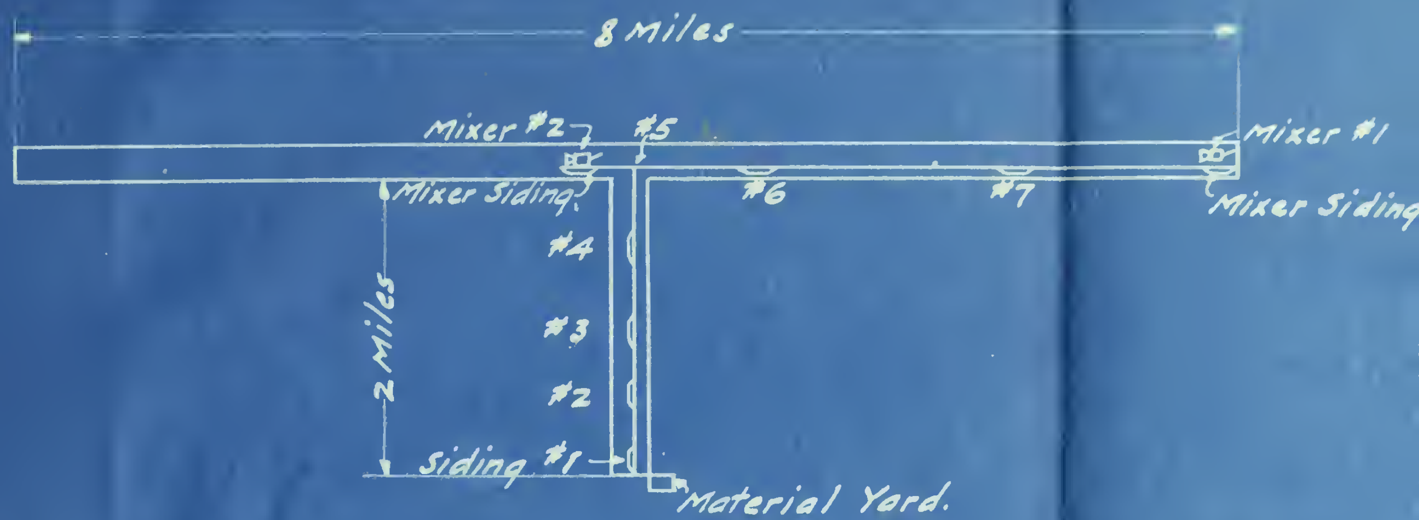


SIDING LOCATION GRAPH
for
BOTH MIXERS AT POINT OF AVERAGE HAUL.

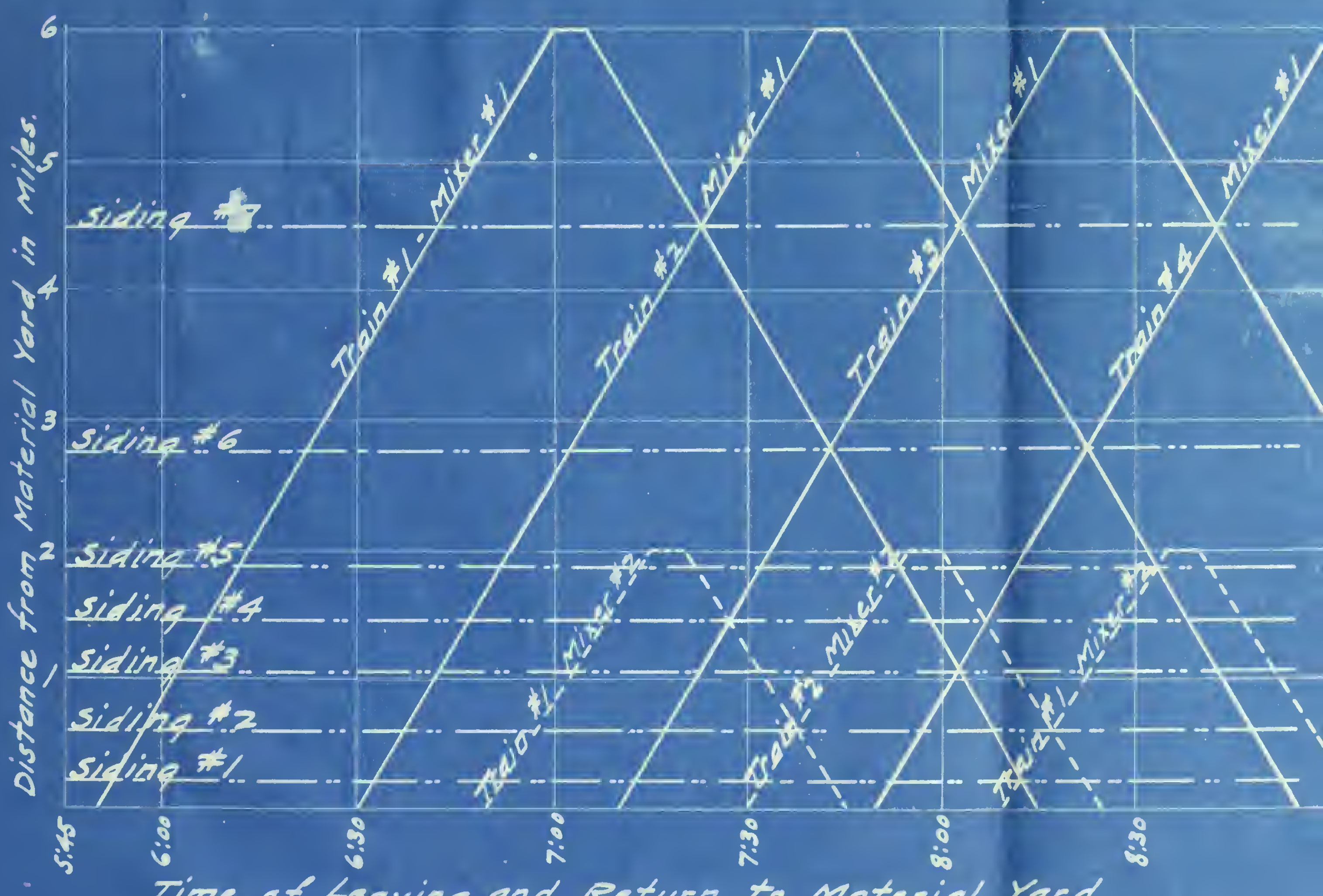


Time of Leaving and Return to Material Yard.
See Schedule No. 1

GRAPH No. 1

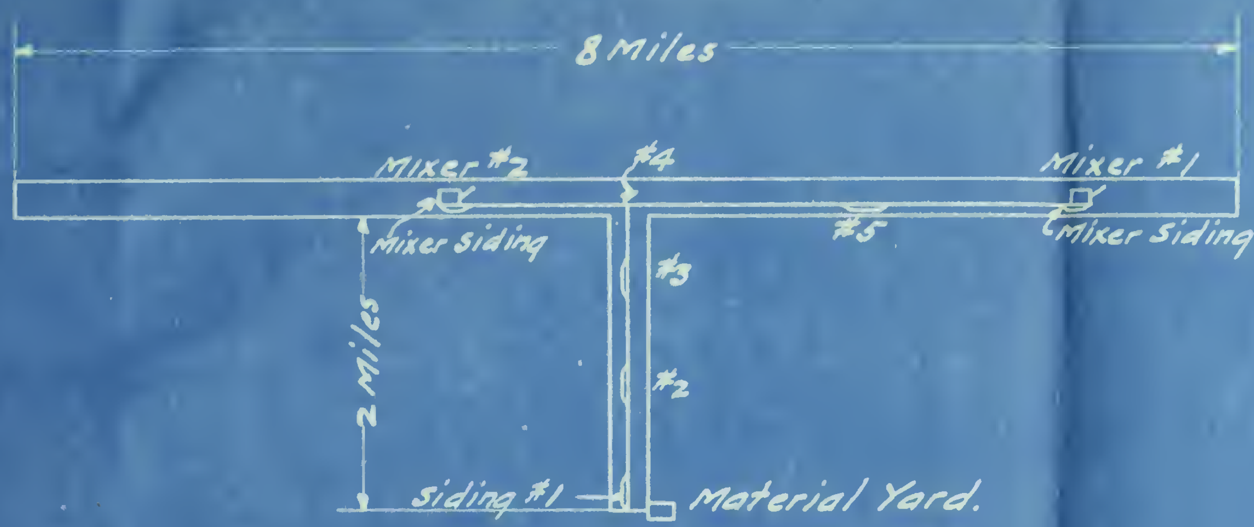


SIDING LOCATION GRAPH
for
MIXER #1 AT MAX. HAUL and MIXER #2 AT MIN. HAUL.

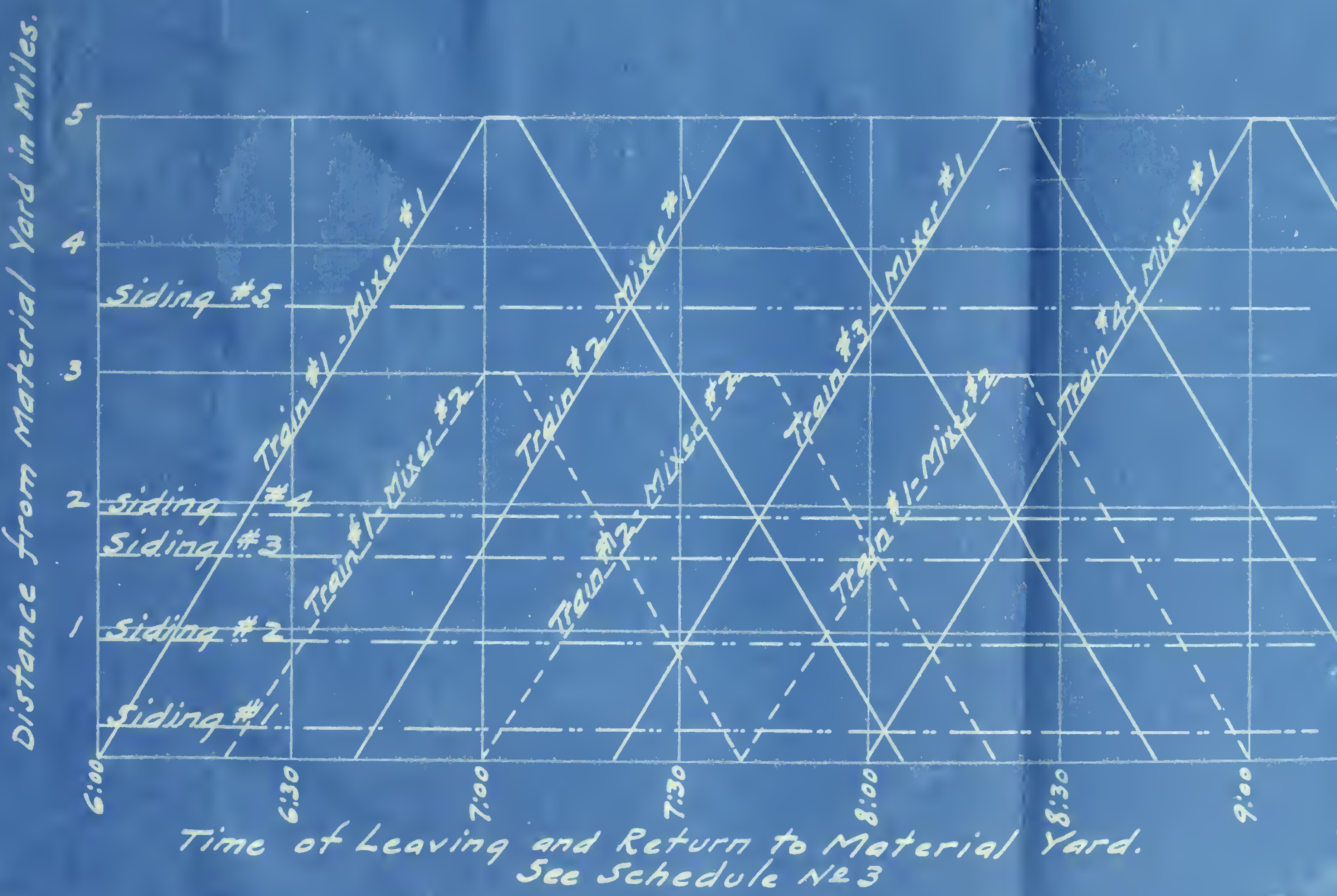


See Schedule № 2

GRAPH № 2



SIDING LOCATION GRAPH
for
MIXER #1 AT 5 MILE POINT and MIXER #2 AT 3 MILE POINT



GRAPH No 3

CHAPTER VIII.

PLAN OF OPERATION

It is extremely difficult, if not impossible, to outline a general plan of operation in highway construction, because local conditions vary so greatly . Some of the more common conditions encountered and plans of operation employed will be described, however, in order to illustrate the application of a road building plant to changing conditions. The application of both a complete railway plant and a combined light railway and motor truck plant, will be considered.

Under the subject of a complete railway plant, we will consider the following cases:

One mixer plant, unloading point at one end.
One mixer plant, unloading point near middle.
One mixer plant, stone at one end and sand at the other.
Two mixer plant, unloading point at one end.
Two mixer plant, unloading point near middle.
Two mixer plant, unloading points at each end.

A job suitable for a one mixer plant with the unloading point at or near one end, is one which is frequently seen in practice. The best plan of operation on such a job is to start grading at the end of the road nearest the material yard, and to continue grading operations straight thru to the other end. As soon as a few hundred feet of subgrade are ready, mixing operations can be started and carried on continuously to the other end. The fact that the laying of concrete can be begun at the point of minimum haul, is one of the big advantages of light railway haulage. Not only is delay due to waiting on the completion of grading eliminated, but concrete and grading operations can be carried on simultaneously. Moreover the most profitable portion of the concrete, the short haul portion, is done first, and this, combined with the simultaneous performance of concreting and grading operations, insures a large payment from the state early in the life of the job. The working capital generally so urgently needed at the beginning of a job, is thus provided.

Two methods of handling a job suitable for a one mixer plant with the unloading point at or near the middle of the job, are in general use. One method is to start grading operations at the point nearest the material yard, and work towards either end of the road. As soon as a few hundred feet of subgrade have been prepared mixing operations are started, and follow closely behind the grading. When the mixer reaches one end of the job it is brought back to the point where it first started, and is then operated towards the other end. All of the track used in the first half is removed, and relaid for use on the second half. This plan permits simultaneous performance of concreting and grading operations, with the attendant advantages pointed out in the preceding paragraph. It is necessary, however, to bring the mixer back around the concrete already laid after it reaches the end of the road, in order to permit it to proceed from the point where it first started to the other end. In the absence of suitable side roads, the operation of bringing the mixer back might prove to be impossible or extremely difficult without considerable delay.

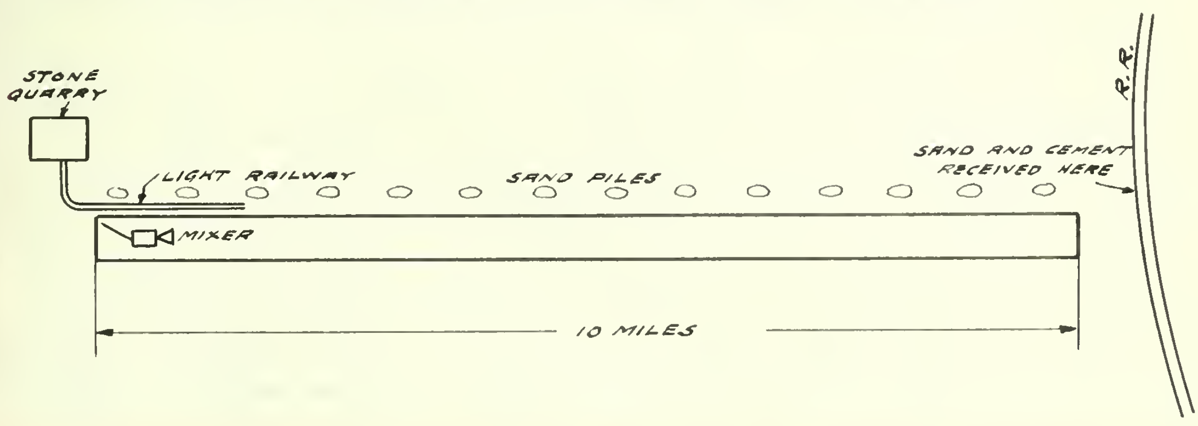
Where conditions are such that to move the concrete mixer from one end

of the road back to the point where it first started is very difficult, or impossible, the best method will be to start the mixer at one end of the road and operate it straight thru to the other. The disadvantage of this plan is that the laying of concrete must be started on the most expensive portion of the road, the long haul portion, while the organization is inexperienced and the track is not well bedded. It is frequently necessary, also, to delay concrete operations until all of the grading between the material yard and one end of the road is completed.

One of the big advantages of starting the mixer at the point of minimum haul, aside from the large payment received from the state early in the life of the job, is that the organization is experienced by the time the most difficult portion of the work, the long haul portion, is reached. By this time, also, all of the track has been in place for some time, and is well bedded and surfaced. When the mixer is started at the point of maximum haul, on the other hand, not only must the inexperienced organization do the most difficult portion of the work first, but it must operate over a newly laid track on which maximum speed cannot be attained for some time. It behooves a contractor, therefore, to weigh carefully the advantages and disadvantages of each plan. In general the plan of starting the mixer at the point of minimum haul is preferable, and should be followed if at all practical.

Either of the foregoing plans of operation apply whether the material yard is adjacent to the road under construction, or is located a mile or two to one side, or whether the material yard is exactly at or opposite the center of the job, or is closer to one end than to the other. If the material yard is located at, or opposite, the quarter or third points, the second of the two foregoing plans possess less disadvantages than if the material yard is at, or opposite, the center of the job, for in such a case the delay in starting concreting operations, due to waiting on completion of the grading, is considerably reduced.

Sometimes stone must be received at one end of a job and sand at the other, while cement may be obtained at either or both ends. Such a situation, while about the most difficult in highway construction, can be more easily handled by light railway haulage than by any other method. Perhaps the best way of illustrating the operation of such a job, is by describing an operation planned in Pennsylvania in 1920. A concrete road 10 miles long was to be constructed in an entirely new location, through very rugged country, in which the grading, mostly shale, averaged some 15,000 cubic yards per mile. The lowest bid received was about $105,000 per mile, which gives some idea of the character of the work involved. Sand and cement were available at the railway at the lower end of the job, while stone was to be obtained by opening up a quarry near the upper end of the road. The sketch below shows a straight line layout of the road.



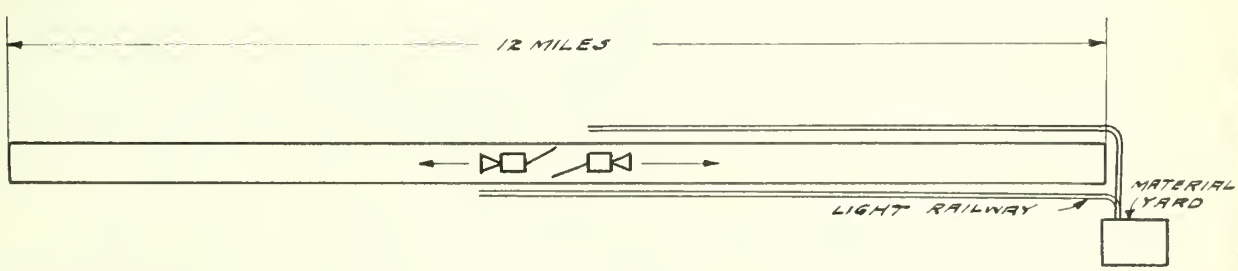
On a job of this kind it is necessary first of all to complete the grading, inasmuch as it is impossible to haul material from one end to the other until this is done. The amount of grading on this road is sufficient to keep two steam shovel outfits busy during an entire working season, though it might be possible to do a good deal of the grading in the winter time if the contract was awarded in the fall. After the grading was completed, in case any method of haulage other than light railway was employed, it would be necessary to place on the subgrade all the stone required, before mixing operations could be started. The mixer would then be started at the point of the road nearest the stone supply, and sand and cement hauled out as required. It is obvious that once the laying of concrete had begun, it would be impossible to haul past the uncured concrete by any other method than light railway in case additional stone was needed to replenish a shortage. The difficulty of distributing just the proper amount of stone is obvious, especially in view of the fact that the subgrade must be trimmed by hand and the wheels of the vehicles hauling material will cut up the subgrade considerably. In practice a surplus of stone would probably be placed on the subgrade, in order to prevent the likelihood of a shortage and delay in concreting. This surplus would then be wasted on the shoulder of the road from time to time, because it would be uneconomical to stop the mixer in order to permit of salvage. Even if the material thrown on the shoulder of the road could be salvaged when the pavement was completed, the cost of picking it up and shipping it to another point would be more than the material is worth. Not only would this method of operation involve a considerable wastage of stone, but to haul sand and cement such a long distance over the subgrade, obstructed as it is by the stone, would be very difficult. On this particular job there were no side roads, and in case it should become necessary to haul stone to replenish a shortage, it would be necessary to suspend the laying of concrete until all of the pavement already laid was sufficiently cured to carry traffic, in case any other method of haulage than light railway were used.

The combined light railway and motor truck method of operation was recommended on this job, renting the motor trucks very cheaply from the state. With this plan of operation, as with any other, it was necessary first of all to complete the grading. Inasmuch as bids were asked in the early spring, the contractor planned to devote all of the first season to grading by means of two steam shovels. Just before freezing weather set in, he planned to drag the road so as to put it in fairly smooth condition for hauling. During the winter time material was to be hauled by motor trucks from the railroad and distributed in piles, each pile containing sufficient sand to build one-fourth to one-half mile of road, depending upon the room available. The mixer was to be started at the end of the road nearest the stone supply, and about two miles of light railway track laid on the shoulder. Until the concrete mixer reached the end of the track, stone could be loaded directly into batch boxes at the quarry and carried by the train to the mixer. As the train passed a sand pile, it would take on the proper amount of sand and cement, which had previously been placed there. The sand was to be loaded into a small portable bin by means of a bucket elevator and a small power scraper, and was to be charged directly into the batch boxes as they passed underneath on their way to the mixer. As each sand pile was exhausted, the bin would be moved on to the next one. By the time the mixer reached the end of the track, a certain amount of the concrete would be sufficiently cured to carry traffic. Motor trucks would then be used to haul stone from the quarry over the finished pavement as far as specifications permitted, dumping the stone on the pavement near a small portable bin. This bin would be equipped with a bucket elevator and a small power scraper, in a manner similar to the sand bin. The light railway trains would thus pass under the stone and sand bins in succession, and take on the proper amounts for each batch. As the concrete hardened the stone and sand bins would be advanced

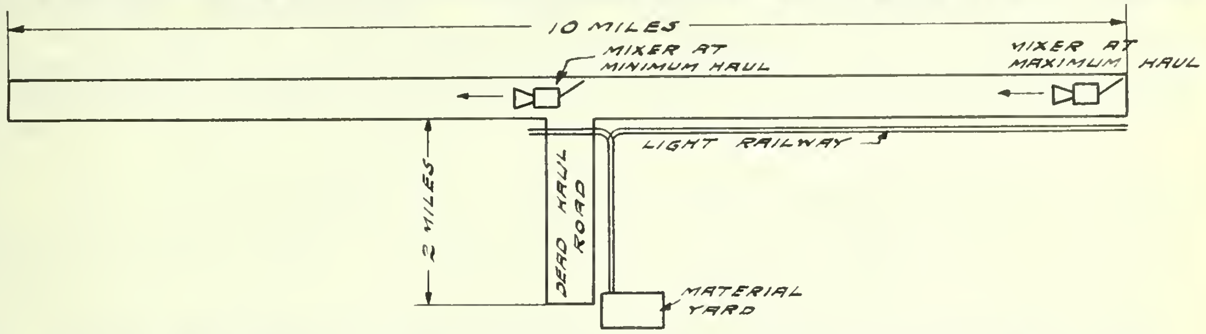
periodically, and the track no longer required in the rear picked up and relaid in advance of the mixer. If desired, the hauling of sand could be postponed until shortly before the laying of concrete began. Cement would be hauled out and stored at each sand pile just in advance of the mixer. In case an improper amount of sand was stored in a pile, this method of operation would enable the supply to be readily replenished. The waste of stone, involved in the method of operation described in the preceding paragraph, would be avoided by the combined light railway and motor truck method.

With a two mixer plant, we can so plan the operation as to produce what is known as a balanced haul. This consists of starting one mixer at the point of minimum haul, and the other mixer simultaneously at the point of maximum haul. It is obvious that if these mixers are of the same size, they should operate at approximately the same rate of speed. The amount of equipment released by the machine which started at the point of maximum haul, as its haul decreases, is just about sufficient to make up the shortage constantly occurring at the mixer whose haul is increasing. If, then, we provide sufficient rolling stock for two mixers based upon the point of average haul, we will have sufficient equipment to supply both mixers at all points by transferring from one to the other as occasion arises. With a one mixer plant, we are confronted by the problem of deciding as to just what length of haul the rolling stock should be proportioned for. If we proportion it for the point of average haul we will have an insufficient amount when the haul exceeds the average, while if we proportion it for the point of maximum haul we will have a surplus as soon as the haul is less than the maximum. By operating two mixers on a balanced haul, however, all of the equipment will be kept busy at all times.

Sometimes it is necessary or desirable to use two mixers on a road, where the unloading point is located at one end. These mixers can be operated on a balanced haul in the following manner: Start both mixers at the center of the road, operating them away from each other toward opposite ends of the job. Lay a line of track for each mixer on opposite shoulders of the road. If these mixers are of the same capacity, they should operate at about the same rate of speed. As one mixer approaches the material yard, and its length of haul decreases, it will release track and rolling stock sufficient to make up the constantly occurring shortage at the other mixer, which is operating away from the material yard. This operation is continued thruout the job, the surplus equipment released by one mixer being immediately put into service in supplying the other. This plan of operation required but slightly more track than if only one mixer is employed. It does, however, involve the laying and removing of 50 per cent greater mileage of track, because a line of track equal to half the length of the road is first laid on each shoulder after which the track on one shoulder is extended to the far end of the road. The sketch below illustrates an operation such as we have in mind.

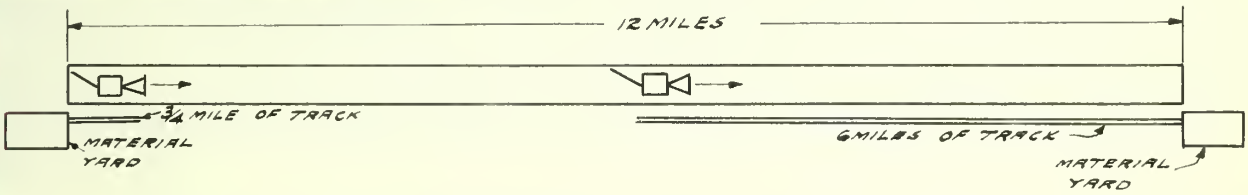


A job suitable for a two mixer plant with an unloading point at or opposite the center of the road, is one frequently seen in practice. Such a job is well adapted to the application of a balanced haul. The sketch below illustrates a 10 mile job with the unloading point opposite the center and 2 miles away.



Start one mixer at the point of intersection of the "dead haul" road with the 10 mile road, the point of minimum haul, and the other mixer and the point of maximum haul at the end of the road. Operate both mixers simultaneously in the same direction, transferring equipment from one to the other as occasion demands.

A balanced haul can be applied very nicely to a job with unloading points at each end, by starting one mixer at the middle of the job and the other at one end. The mixers should be operated simultaneously in the same direction, and should be supplied from separate material yards. The layout of such a road is shown in the following sketch.



The plan of operation outlined above will require an amount of track but slightly greater than half the length of the road, for as equipment is released from the mixer which started at the middle, it is transferred to the mixer which started at one end. This plan of operation requires less track than where all the material must be hauled from one end, and the mileage of track to be laid and removed is equal to the length of the road. The operation of a two mixer plant with a material yard at each end of the road involves less track laying and less ton mileage than where all material must be hauled from one end, but it necessitates the operation of two material yards. Whether it is more economical to establish and operate two material yards than to haul all material from one end, depends upon the decrease in the ton mileage resulting therefrom and must be left to the individual judgment of the contractor. As a rule, unless the cost of establishing the second material yard is excessive, it will generally be found that the saving due to the decreased ton mileage and the decreased amount of equipment required will justify two yards.

Still another method of operating a two mixer plant on a balanced haul when all material must be hauled from one end, is by starting one mixer at the far end of the road and the other at the end nearest the material yard. Both mixers should be operated towards the center of the job, and as equipment is released

by the mixer which started at the far end it is transferred to the mixer which started at the near end. This plan possesses no particular advantage over the plan previously described, of starting both mixers at the center of the job and working them away from each other. Track for supplying each mixer should preferably be laid on opposite shoulders, though it is possible for a contractor of good organizing ability to supply both mixers from one line of track. If he can supply both mixers from one line of track, he will save the cost of laying and removing an amount of track equal to half the length of the road.

In all of the preceding discussion we have considered only the complete railway plant. The combined light railway and motor truck plant can be applied in much the same way. On a job suitable for a one mixer plant with the material yard at one end, the best plan of operating a combined light railway and motor truck plant is to start the mixer at the point of minimum haul, as soon as a few hundred feet of subgrade have been prepared. If the material yard is located directly at the end of the road, material can be hauled by light railway until the mixer reaches the end of the 1-1/2 miles of track commonly employed in this typeof plant. If the material yard is located some distance from the beginning of the job, material can be hauled in batch boxes on motor trucks to the beginning of the job, where it can be transferred to the railway, by means of a portable derrick, for haul to the mixer. By the time the mixer reaches the end of the railway track a certain amount of the pavement already laid will be sufficiently cured, according to specifications, to carry traffic. While the mixer may only operate 20 days per month, or say two-thirds of the time, Sundays and holidays and other days during which the mixer does not run are just as valuable for curing concrete as are working days. Each day, as another section of concrete comes of age, the transfer point is advanced by dragging forward the portable derrick, and the track no longer required in the rear is relaid in advance of the mixer. If the mixer operates at an average of 400 feet per day, the transfer point can be advanced at approximately the same rate daily. The advantage of this plan of operation, due to the fact that concreting and grading can be carried on simultaneously, has been previously pointed out.

A road with the unloading point at or opposite the middle of the job, or some point between the middle and the end, can be handled in the manner outlined in the previous paragraph. The mixer can be started at the point of minimum haul and operated away from the material yard towards one end, after which it is brought back and operated towards the other end, or it can start at one end of the job and operate continuously thru to the other end.

The method of handling a job suitable for a one mixer plant with sand and stone at opposite ends, by means of a combined light railway and motor truck hauling plant, has previously been outlined in describing a 10 mile road in Pennsylvania.

A two mixer plant with the unloading point at one end of the job, can be supplied by means of a combined light railway and motor truck plant in the following manner: Start one mixer at the point of minimum haul and the other mixer at the half way point, supplying 1-1/2 miles of track to the mixer at the point of minimum haul and a length of track equal to half the length of the road, plus 1-1/2 miles, to the mixer at the half way point. If the unloading point is located exactly at the end of the job, the mixers can be supplied by means of light railway haulage entirely until they reach the end of their respective tracks. If the unloading point is some distance from the beginning of the road, material can be hauled in batch boxes on motor trucks to the beginning of the road and there

transferred to the railway. By the time the mixers reach the end of their respective lines of track, a portion of the concrete already laid by the first mixer, operating at the minimum haul, is sufficiently cured to carry traffic. From then on the regular method of operating this type of plant is followed, advancing the transfer point as the concrete hardens and removing track in the rear and relaying it in advance of the mixer. The plan of operation just described will require almost as much track as if a complete railway plant were used, and there is, therefore, no particular merit in it. If the job is large enough to require two 14-E paving mixers and it is still desired to employ the combined light railway and motor truck plant, it would be preferable to employ a 28-E paver rather than two 14-E's. A 28-E operated on the combined principle with 2 miles of track, would work very nicely.

If the unloading point is at, or opposite, the middle of the job, and it is desired to use two paving mixers supplied by the combined light railway and motor truck plant, the best plan would be to start both mixers at the point of minimum haul and operate them away from each other toward opposite ends of the road. This operation, in effect, is exactly the same as if two separate jobs were operated with an unloading point at the end.

In the case of a job with an unloading point at each end, a two mixer plant can be operated by the combined light railway and motor truck method by starting the mixer at the points of minimum haul and operating them towards each other so that they will meet in the middle. The regular method of operation with a combined plant will be in effect here.

The fundamental idea underlying operation with a light railway haulage plant, or a combined light railway and motor truck plant, in highway construction, is to start the mixer at the point of minimum haul. In case of a two mixer plant start one mixer at the point of minimum haul and the other at the point of maximum haul, so as to secure a balanced haul. The laying of concrete can then be started as soon as a few hundred feet of subgrade have been prepared, thus eliminating the delay that generally occurs in placing concrete due to the necessity of waiting for completion of the grading, when any method of haulage other than light railway is used. Not only is this delay eliminated, but the laying of concrete and grading can be performed simultaneously. The most profitable portion of the concrete, the short haul portion, can be done first, and this, in conjunction with the simultaneous performance of concreting and grading, insures a large payment from the state early in the life of the job. The working capital, always so badly needed at the start of a job, is thus provided. By starting the mixer at the point of minimum haul the organization is experienced by the time the most difficult portion of the work, the long haul portion, is reached, and the track is well bedded.

With either the complete railway system or the combined light railway and motor truck system, all hauling is done over steel rails or improved roads. Delay due to rain should thus be reduced to a minimum. Of course, when the unloading point is located some distance from the road under construction and the combined system is used, the road leading from the unloading point is not always of the best. Operation over this road, however, is no more serious than if some other method of haulage were used, and the cutting up of it is by no means as serious or costly to the contractor as is the cutting up of the subgrade.

CHAPTER IX.

HAULAGE EQUIPMENT REQUIRED.

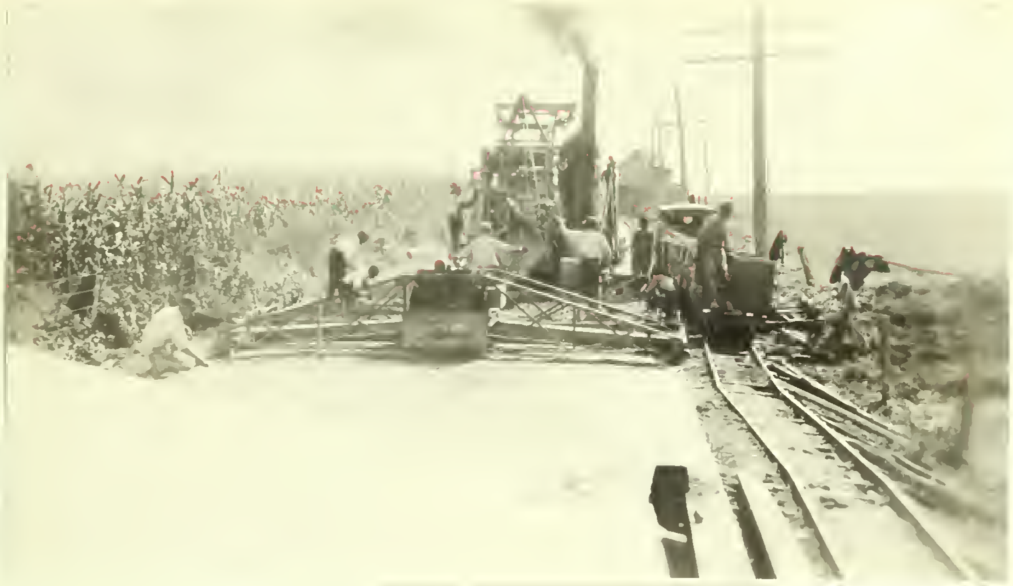
In this chapter we will consider all of the light railway rolling stock and the necessary amount of track and passing sidings required, as well as all motor truck equipment used in conjunction with the light railway in a combined light railway and motor truck plant.

The rolling stock and track required, varies not with the length of the road but with the length of haul. In case of a 10 or 12 mile job, it is generally possible to establish unloading points so that not more than 3 or 4 miles of track are needed. When the unloading point is located at one end, however, it is necessary to use an amount of track equal in length to that of the road, except where the combined system of haulage is employed.

In proportioning the amount of rolling stock, except in case of a balanced haul, we are confronted with the problem of basing our computations on the average haul, on the maximum haul, or on some point in between. If we adopt the average haul as the basis for the rolling stock required, we will have an insufficient amount as soon as the haul exceeds the average. The capacity of the haulage plant between the points of average and maximum haul, in such a case, is insufficient to supply the mixer at the proper rate. If we base the amount of rolling stock upon the maximum haul, on the other hand, we will have a surplus on all hauls below the maximum. This will insure operation of the concrete mixer at full capacity at all times, but the method is uneconomical due to the surplus rolling stock which is idle a good deal of the time. Experience indicates that a length of haul about half way between the average and the maximum, is the proper one upon which to base the rolling stock required. In other words, when material must be hauled from one end of a job to supply a single mixing plant, proportion the rolling stock upon a basis of three-fourths of the maximum haul.

Experience has demonstrated that an average speed of 6 miles an hour for both loaded and empty trains, is the proper speed to use in determining the amount of rolling stock needed to supply the mixer. In rolling country, where the down grades balance the up grades fairly well in both degree and length, this average speed of 6 miles per hour can also be used in making rolling stock computations. In special cases, where the preponderance of ascending grades is opposed to the loaded trains, it might be necessary to compute the weighted mean speed as described in a previous chapter.

In operating a light railway plant some contractors prefer to keep the locomotive attached to the train, while it is being unloaded at the mixer and loaded at the material yard. Other contractors prefer to detach the locomotive and immediately pick up another train. The decision as to which method to adopt depends upon local conditions, and frequently both methods are used in the same job. Where long trains of 10 to 20 cars are used, it is generally more economical to detach the locomotive at the mixer and return at once to the material yard. In such a case the train at the mixer is moved by means of a team of horses, the road roller, or by hand. Where small trains of only 3 or 4 cars are used, it is generally preferable to keep the locomotive attached to the train at the mixer during the unloading process, except where the split train method is used. Even in hilly country it is seldom necessary to use such small trains, except for a small proportion of the time.



LOCOMOTIVE ATTACHED TO TRAIN AT MIXER

The question of whether to detach the locomotive from the train at the material yard during the loading process, is governed by the same conditions as at the mixer. When the tunnel system of storage is used, the switching of the train at the material yard is frequently effected by means of a small hoisting engine set at one end of the tunnel . Sometimes an endless cable is passed thru the tunnel,and around sheaves so as to pass outside of the material pile. A team hitched to this cable on the outside can then be used to shift the train in the tunnel. Many tunnels are constructed on a slight grade, about one-half of 1 per cent, so that the shifting of the train is facilitated thereby. Experience has shown that where the tunnel system of storage is used, an allowance of one minute per batch is sufficient for completely charging a train at the material yard. To load a 10 car,20 batch train, therefore, will require 20 minutes, and in computing the running time of a locomotive,which remains attached to the train during loading, this allowance should be made.

When material is hauled from one end of a job to a one mixer plant, the rolling equipment is generally based upon three-fourths of the maximum haul. On all hauls less than three-fourths of the maximum, a surplus of rolling equipment will be on hand, and during this period it is generally feasible to keep the locomotive attached to the train at the mixer during the unloading process, if desired. Later on, as the haul increases to the point where time is not available for keeping the locomotive at the mixer or at the material yard during the unloading and loading process, the locomotive can be detached from the train at one of these points. Still later on as the length of haul increases, it will probably be necessary to detach the locomotive from the train at both the mixer and the material yard.

If the locomotive is detached at the mixer and at the material yard, an additional train of cars must be provided at each point. For instance, if only 3 locomotives are in use and they remain attached to the trains during all operations, but 3 trains are required. If the trains are dropped at the mixer and the material yard, however, an additional train must be provided at each of these points, making 5 all told. In considering the question of detaching locomotives at the mixer and at the material yard, the cost of additional cars and the cost of switching by means of team, hoisting engine, or by hand, must be compared to the

cost of the additional locomotives which might be required and their cost of operation. In the majority of cases it is more economical, as a rule, to detach the locomotives from the train at the mixer and the material yard, than it is to keep them there during the process of unloading and loading. Where 6 ton locomotives are used for hauling, 3 ton machines are sometimes provided for switching trains at the mixer and at the material yard.

In charging the mixer by means of batch boxes carried on cars, it is necessary to move the car for each batch so as to permit clearance when the mixer derrick picks up a box. In level country the problem of moving cars is not serious, and is almost always done by hand by detaching and moving one car at a time. A single horse is sometimes used to haul the empty cars to the switch, which is never more than a few hundred feet from the mixer. As a rule, however, the passing siding is kept close to the mixer, not more than one-half or one day's run away, and the locomotive arriving with the loaded train has plenty of time to switch the empty.

SWITCHING CARS WITH A HORSE

SWITCHING CARS BY HAND

PASSING SIDING NEAR MIXER

In hilly country the problem of switching cars at the mixer is somewhat more difficult than in level country, due to the grades. When the locomotive is detached from the train at the mixer, the train should be left standing on the up-hill side of the mixer. Cars used in hilly country are generally all equipped with brakes, and they can be let down to position near the mixer either singly or in trains. Single cars can easily be controlled by means of their brakes, or by means of a stick of wood pressed against a wheel. After being unloaded the cars are dropped down grade some distance, where they are again formed into a train at a siding. When it is desired to switch entire trains on steep grades in order to permit unloading, some other method of control than brakes must generally be used. This is due to the fact that the brakes on each car operate independently of the other, and there is no means of controlling all the brakes in a train as a unit. A method frequently used, in such a case, is to "snub" a rope around a tree or an anchor post at one side of the track, pass it thru a sheave in the center of the track, and attach it to the train. Still another method of shifting trains as a unit on grade, is by means of a line attached to the road roller. The passing siding should always be placed on the down grade side of the mixer, so as to permit the empty cars to be coasted down to the siding and there formed into a train.

Consider now a road 5 miles long, with an unloading point at one end. The amount of track required is equal to 5 miles, plus a certain amount for passing sidings and for the material yard. The amount of track needed for passing sidings cannot be determined until the number of sidings are known, and this in turn depends upon the number and size of trains. As a rule, however, a passing siding every mile is sufficient where but one mixer is to be supplied. The length of passing siding depends upon the size of trains. The overall length of a car from coupling to coupling is about 8 feet, so that a 10 car train with a locomotive will require about 90 feet in the clear. To allow a little extra we will provide 105 feet of clear track in the siding, inasmuch as this is exactly equal to 7 sections of track. In case it is desired to determine the exact number of sidings necessary, a time schedule should be computed and a graphical determination made from it. In the case in point, we will provide one passing siding at the mixer and 4 along the line. At the mixer we will provide 795 feet of track, inasmuch as this is exactly equal to 53 sections. The total amount of track provided on this job, therefore, will equal 5.25 miles.

The switch and a special straight and curved section required to form one end of a passing siding, is known as a half turnout. Two of these are required at each passing siding, while at the material yard we will provide 4 more. This makes a total of 14 half turnouts all told on this job. Details of a half turnout will be found on page 24 of bulletin #29-D of The Lakewood Engineering Company, which is included in the appendix.

Special curved sections 7-1/2 feet in length of 30 foot radius are provided, 6 of which will subtend a central angle of 88 degrees and 45 minutes. Curves of lesser degree can be obtained by using fewer curved sections. The number of curved sections to be provided on a job depends upon local conditions. In this case we will assume one 90 degree bend in the road, and at the material yard 3 more. It is necessary, therefore, to provide about 25 curved sections for this job.

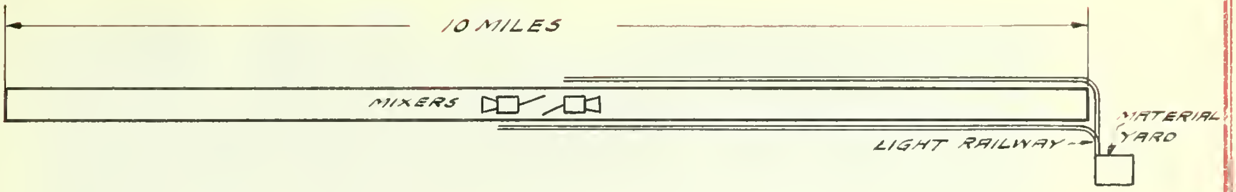
The rolling stock will be based upon a haul of three-fourths of the maximum, or 3.75 miles, and upon a speed of 6 miles per hour. An allowance of 5 minutes will be made for switching trains at the mixer, and the same amount of time at the material yard. The controlling grade will be assumed at 3 per cent, enabling a 6 ton locomotive to haul a train of 7 to 8 cars, each carrying 2 - 4 bag batches of material for 1-2-3 concrete. Such a car will weigh 3.4 tons, with sand at 3,000 pounds per cubic yard, stone at 2,700 pounds per cubic yard, and cement at 374 pounds per barrel.

The running time of the train, based upon the foregoing data, will be 85 minutes per round trip on a 3.75 mile haul. This is equivalent to 7 round trips per 10 hour day, enabling each locomotive to deliver 98 batches to the mixer. Three locomotives are, therefore, required to supply the mixer with 300 batches per day. Five trains of 7 cars each, or a total of 35 cars and 70 batch boxes, must be provided.

The amount and cost of the railway equipment needed on a job of this kind, based upon prices in March, 1921, is as follows:

EQUIPMENT	COST	WEIGHT
$5\frac{1}{4}$ miles straight track @ $6,318.40	$33,171.60	637,560 lbs.
14 half turnouts @ $150.00	2,100.00	15,190 "
25 curved sections @ $13.95	348.75	4,625 "
35 batch box cars @ $115.00	4,025.00	38,500 "
70 batch boxes, 25 cu.ft. cap. @ $71.20	4,984.00	28,000 "
3 - 6 ton gasolene locomotives @$4,600.00	13,800.00	37,300 "
2 platform cars, general utility, @ $415.00	830.00	4,000 "
	$59,259.35	765,175 lbs.

The sketch below shows a road on which it is desired to operate two paving mixers, supplying them by means of a complete railway haulage plant from an unloading point at one end. The mixers will be operated on the balanced haul principal, by starting at the center of the road and working away from each other toward each end. Inasmuch as these mixers are of the same size, the rate of operation of each should be about the same. The equipment released by the mixer operating on the decreasing haul, therefore, should be just about sufficient to provide for the shortage at the mixer operating on the increasing haul. Rolling stock provided for two mixers at the point of average haul, therefore, should be sufficient to keep each mixer fully supplied at all times by transferring from one to the other as occasion requires.



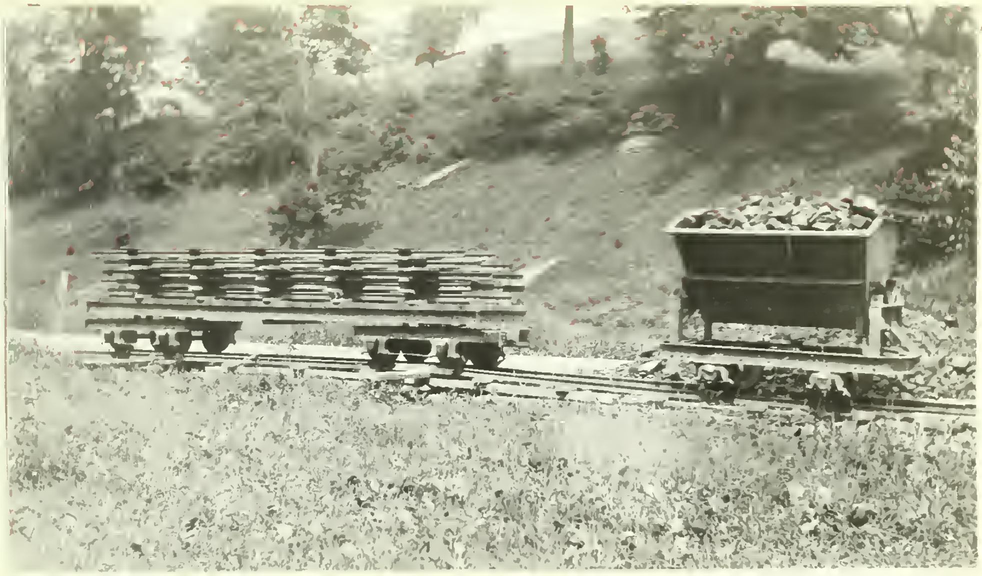
The amount of track required for the two mixer plant, is slightly more than twice that for the one mixer plant previously considered. This is because a small amount of extra track is provided, to take care of delay in moving equipment from one mixer to the other. We will allow an extra quarter mile for this purpose, making a total of 10-3/4 miles required for this job. The rolling stock will be based upon the full haul of 5 miles, rather than three-fourths of 5 miles as in the single mixer job.

Five passing sidings will be provided for each mixer, making a total of 24 half turnouts, including 4 at the material yard. Assuming one 90 degree bend in the road and 3 at the material yard, a total of 30 curved sections are needed.

The running time of a locomotive per round trip on the 5 mile average haul at 6 miles per hour, allowing 5 minutes for switching trains at the mixer and 5 minutes at the material yard, is 110 minutes. This is at the rate of 5 round trips per 10 hour day. Assuming an 8 car train, each locomotive will deliver 80 batches per day to the mixer so that 4 locomotives are needed to supply at least 300 batches. Six trains of 8 cars each and 16 batch boxes must be assigned to each mixer, and the total amount of equipment required for two mixers would be approximately twice that required for one. Inasmuch as 4 locomotives and 6 trains possess somewhat greater hauling capacity than is required by one mixer, we will provide a total of 7 locomotives and 11 trains for two mixers instead of doubling the amount required for one.

In addition to the equipment listed in the foregoing, it is necessary to provide at least 2 double truck platform cars for the purpose of moving track from one mixer to the other and for general utility haulage. The cost of the plant outlined for the two mixer job shown in the sketch above, can be computed as in the previous example. When mixers are operated on the balanced haul they can be operated at a full rate of speed at all times, due to the fact that track and rolling stock can be transferred from one to the other as desired. Furthermore, the rolling stock is kept busy at all times, and the problem of a surplus or a shortage of haulage equipment is eliminated. The investment in haulage equipment per mixer is less when mixers are operated on a balance haul, than where but one mixer is to be supplied. This is obvious when we consider that haulage equipment for a one mixer plant is based upon a length of haul equal to three-fourths of the maximum, while haulage equipment for a mixer operating on a balanced haul is based upon the average haul.

A two mixer plant with the unloading point near the middle of the job and immediately adjacent to or some distance from the road, can be operated very nicely on the balanced haul principle. Less track is required in such a case, then where all material must be hauled from one end. The most expensive type of operation is that where all material must be hauled from one end of the job. If possible an unloading point should be secured as near the center of the job as conditions will permit, for the investment in haulage equipment, as well as the ton mileage, is thereby considerably reduced.



GENERAL UTILITY PLATFORM CAR

The fundamental idea to be kept in mind in operating mixers upon the balanced haul principle, is that equipment should be based upon the average haul. The amount of equipment required for two mixers is, therefore, approximately twice that required for one. The investment in haulage equipment per mixer is less in a two mixer plant operating upon a balanced haul, than in a one mixer plant.

The general characteristics of a combined light railway and motor truck haulage plant for highway construction, have already been described. The fundamental idea of this plan of operation is to haul material by motor truck over that portion of the concrete which, according to specifications, is sufficiently cured to carry traffic, and to transfer material at this point to a light railway train for haul past the uncured concrete to the mixer.

A good organization with an adequate supply of materials, should lay about 400 feet of 18 foot concrete road per 10 hour day with a 14-E mixer. In a normal season about 20 working days per month should be obtained, and at this rate 14 working days should be obtained during the 21 day curing period which most states require before permitting traffic on the concrete. At a rate of 400 feet per day, the mixer should lay about 5,600 feet of road in 14 working days. The minimum amount of track that must be provided for hauling material from the transfer point to the mixer is, therefore, 5,600 feet. To allow for failure to move up track promptly, slow curing of concrete, or for more than 14 working days during the 21 day curing period, it is wise to provide 1-1/2 miles of track for a combined light railway and motor truck haulage plant.

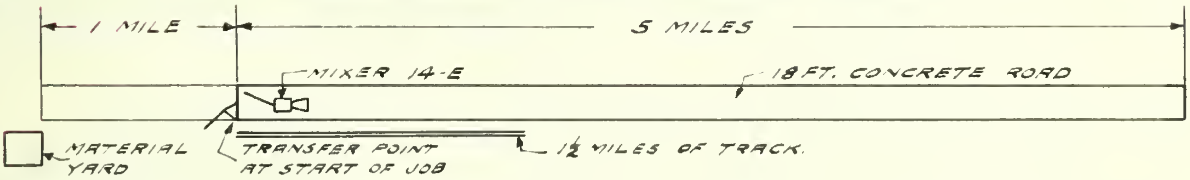
Two passing sidings, one at the transfer point and one near the mixer, will be sufficient, so 4 half turnouts must be provided. The number of curved sections will depend upon each individual road, but in this case we will assume 10 sections to be sufficient.

A 5 ton motor truck will carry 4 batch boxes, each containing properly proportioned materials for a 4 bag batch of the mixture generally specified in concrete road work, while a 3-1/2 ton truck will carry 3 such batches. A sufficient number of batch boxes must be provided to equip the maximum number of trucks needed at the maximum haul.

BATCH BOX HAULAGE WITH 3-1/2 TON TRUCK

In determining the amount of motor truck equipment needed, a speed of 6 miles per hour loaded and 10 miles per hour empty is a good average over earth or macadam roads in fairly good condition. On hard surfaced roads, an average speed of 10 miles per hour for a 5 ton truck both loaded and empty is about right. Experience has shown that an allowance of 5 minutes at the material yard for loading 4 batch boxes and 10 minutes at the transfer point, is ample.

LOADING TRUCK, BATCH BOX HAULAGE SYSTEM



COMBINED LIGHT RAILWAY AND TRUCK SYSTEM.

TRANSFERRING BATCH BOXES FROM TRUCK TO CARS

The sketch at the bottom of page 65 shows the layout for a combined light railway and motor truck haulage plant applied to a 5 mile job, the unloading point for which is located 1 mile from one end. The best plan of operation is to start the mixer at the end of the road nearest the unloading point, as shown in the sketch. Loaded batch boxes will be hauled by motor truck to the beginning of the job, where they will be transferred to light railway cars by means of a small crane shown in the photograph above, or by means of a portable derrick shown in illustration below.

PORTABLE DERRICK FOR TRANSFERRING BATCH BOXES

The transfer point will be maintained at the beginning of the job until the mixer, which operates at about 1.25 miles per month, is near the end of the track. By this time about half of the concrete laid is 21 days old. The transfer point will then be advanced as far as possible by moving up the portable derrick, and the track no longer required in the rear will be picked up and relaid in advance of the mixer. This operation will be repeated each day, or every two days, as additional concrete comes of proper age to carry traffic.

We will assume that the road between the material yard and the beginning of the job is not improved, so that an average speed of 6 miles per hour loaded and 10 miles per hour empty is all that can be expected from the trucks. At this rate, allowing 5 minutes for loading and 10 minutes for transferring, the round trip on the 1 mile haul will be performed in 31 minutes. This is at the rate of

19 round trips per 10 hour day, and inasmuch as each 5 ton truck carries 4 batches, it will deliver 76 batches per day to the transfer point. To provide a supply of 300 batches, will require the services of 4 trucks.

The maximum haul for trucks will be 1-1/2 miles from the far end of the road, or a distance of 4-1/2 miles. On the first mile of haul the loaded truck will average a speed of 6 miles per hour, and on the remaining 3-1/2 miles over the finished pavement it will average 10 miles per hour. On the return trip an average speed of 10 miles per hour should be attained thruout. Allowing 5 minutes for loading and 10 minutes for transferring, a total of 73 minutes are required per round trip on the maximum truck haul. At this rate a truck will make 8 round trips per day, delivering 32 batches to the transfer point. On the maximum haul, therefore, 9 trucks should suffice, making an average of 6 to 7 trucks thruout the job.

On the motor truck portion of a combined light railway and motor truck haul, it is generally more economical for a contractor to rent trucks than to purchase them. He can then add trucks from time to time as needed. A contractor must distribute all his plant charges over a working season of only some 120 days, whereas a trucking company can distribute its plant charges over a period twice as long. For this reason the trucking company can afford to rent trucks at a smaller per diem rate, than the contractor can operate his own trucks for.

Inasmuch as a maximum of about 9 trucks are required on this job and each truck carries 4 boxes, 36 batch boxes must be provided for the trucks. For contingency 4 more should be added, making a total of 40 in addition to those required by the railway cars.

On the railway portion of a combined light railway and motor truck haul, the locomotive operates continually between the transfer point and the mixer on an average haul of about 1 mile. At a speed of 6 miles per hour, allowing 5 minutes at the mixer and at the transfer point for switching purposes, 30 minutes are required by the locomotive to make a round trip. During this 30 minutes the mixer will consume about 15 batches of material, so that a train of 7 or 8 cars must be used. In case the grades are so steep that a train of only half this size can be used, it will be necessary to provide 2 locomotives. Each locomotive can then haul a train of 4 cars, or they can cooperate in hauling a train of 8 cars. Fewer cars will be needed if 4 car trains are used, instead of 8 car trains. In the case in point, we will assume grades such that an 8 car train can be used.

EQUIPMENT	COST	WEIGHT
1 6-ton gasolene locomotive	$ 4,600.00	12,500 lbs.
24 batch box cars @$115.00	2,760.00	26,400 "
48 batch boxes for cars @ $71.20	3,417.60	19,200 "
40 batch boxes for trucks @ $71.20	2,848.00	16,000 "
$1\frac{1}{2}$ mile straight track @ $6,318.40	9,477.60	182,160 "
4 half turnouts @ $150.00	600.00	4,320 "
10 curved sections @ $13.95	139.50	1,850 "
1 platform car, general utility	415.00	2,000 "
	$24,257.70	264,430 lbs.

The cost of equipment shown in the foregoing table is the current cost in March, 1921.

LOCOMOTIVE AT TRANSFER POINT

TRAIN APPROACHING MIXER, COMBINED SYSTEM

Sometimes material is hauled in bulk in dump body trucks, on the motor truck portion of a combined light railway and motor truck plant. In such a case material is dumped near a small portable bin at the transfer point, into which it is rehandled by means of a bucket elevator and a power scraper, a small crane equipped with a clam shell bucket, or a portable belt conveyor. The batch box system of haulage is preferable to the bulk system, because not only are all proportioning operations concentrated at the material yard but a light derrick can be substituted for the expensive rehandling equipment necessitated at the transfer point by the bulk system. Sometimes it is necessary to employ the bulk system , where the sand, cement, and stone are obtained at widely scattered points. Even when the bulk system of haulage must be resorted to, the combined light railway and motor truck plan possesses big advantages over the method of dumping material on the subgrade or of charging the mixer direct from a truck.

Sometimes the batch box system of haulage is objected to, on the grounds of the dead weight of the boxes. It must be kept in mind, however, that the batch

box system permits a platform truck or a plain truck chassis equipped with a light wooden frame, to be employed as haulage units. Not only does this reduce the cost of rental or purchase of trucks, but it increases the number of units available. Four steel batch boxes of sufficient capacity to contain a 4-bag batch of material for the mixtures commonly employed in concrete road construction, will weigh 1,800 pounds and cost about $280.00. The dump-body for a 5-ton truck will weigh about 2,000 pounds, and will cost about $800.00. In both weight and cost, therefore, the batch box system is superior to the dump-body, bulk-haulage system.

PORTABLE BIN AT TRANSFER POINT

TRUCK CHASSIS EQUIPPED WITH BATCH BOX FRAME

Other equipment used in concrete road construction, is listed in the following table with both its cost and weight. The prices are those prevailing in March, 1921. The equipment as listed is that required for one mixing plant. The derrick at the transfer point would not be needed, of course, in case a complete railway hauling plant is used.

EQUIPMENT	COST	WEIGHT
1 14-E paver, with boom and bucket, batch transfer, 1/2 caterpillar, and batch meter	$ 7,925.00	25,400 lbs.
1 finishing machine	1,800.00	3,000 "
1 subgrade machine	600.00	2,300 "
2000 feet, 6" steel form @ $9.12 per 10 ft. sec.	1,824.00	17,600 "
1 double unit road pump	1,500.00	4,000 "
1 3/4 yard clam shell bucket	700.00	2,530 "
1 derrick at transfer point	1,200.00	

At the material yard, traps are provided in the roof on the tunnel or in the bottom of the bin for the purpose of loading batch boxes. These traps are generally spaced every car length, or approximately 8 feet apart in the tunnel. The type of trap manufactured by The Lakewood Engineering Company especially for handling sand and stone, weighs 94 pounds and costs $23.50.

Two inch diameter wrought iron pipe is the type generally employed in the water supply system for a 14-E or 21-E mixer plant. For a 28-E mixer a 2-1/2 inch pipe should be used. Pipe smaller than 2 inch in diameter should never be used. Two inch wrought iron pipe weighs 3-2/3 pounds per foot and cost, in March, 1921, about $0.30 per foot.

Union should be provided in the pipe line every thousand feet, with gate valves every quarter or half mile. Tees should be provided approximately 80 feet apart, for attaching the hose leading to the paving mixer. An expansion joint should be provided every half mile or so to take care of variations in the length of the pipe line. This is a very important feature, and should not be overlooked. The C. H. & E. Manufacturing Company, of Milwaukee, Wisconsin, manufacture an expansion joint which is quite commonly used, though most contractors prefer to make a home-made affair of a piece of hose or a short cross pipe 3 or 4 feet long.

Complete illustrations and specifications of the equipment mentioned in this chapter will be found in the appendix.

CHAPTER X.

MATERIAL UNLOADING AND PROPORTIONING YARD.

Of all the problems confronting the highway contractor, the problem of receiving, storing, and proportioning material is the most important. Some of the elements of this problem, notably that of receiving material, is largely beyond the contractor's control,and is dependent upon railroad deliveries which are frequently erratic and unreliable. In order to avoid delay from this source, therefore, the prudent contractor provides adequate storage facilities, and takes steps to insure a proper supply of material during the construction season by storing material during the inactive road building months.

In the past the biggest handicap to storing raw material during the inactive season, was due to the large amount of working capital required. At the present time, however, most State Highway Departments have adopted the practice of paying monthly estimates on material, providing it is stored in large stock piles near a railroad. As a rule no payments are made for material distributed along the road in windrows, on account of the possibility for loss. This attitude of State Highway Departments affords an opportunity to practically all contractors to prepare themselves properly for quantity production during the construction season,by storing materials in the winter months.

Payments on cement stored during the winter months are as yet not generally made, due to the perishable nature of the product. Some states, however, notably Pennsylvania, permit contractors to store cement after the fifteenth of February, and make monthly payments on cement so stored. This reduces the amount of time the cement is kept in storage, while it gives the contractor about two months to provide a reserve of cement. When bagged cement is used no payments are made for the bags, and the contractor is compelled to invest $1.00 per barrel in this non-productive item. Bulk cement possesses a big advantage in this respect, inasmuch as no money is tied up in bags.

Contractors are rather wary of storing cement for any considerable length of time, due to the danger of spoiling. Experience in the past justifies caution on their part. The storage of cement so as to prevent spoiling, however, is now better understood than it was in the past. If the cement house is so constructed as to keep out moisture, using tar paper on the walls and floor and storing cement so as to prevent the circulation of air, there is but little danger of spoiling. The great enemy of cement is moisture, and inasmuch as air carries moisture every precaution should be taken to prevent its circulation. Cement should be piled so as to prevent the circulation of air thru it, and should be covered with building paper or canvas.

Due to the difficulty of securing an adequate supply of material during the past two years, some contractors, especially those who were formerly engaged in railroad construction, have purchased and operated their own standard railroad equipment. This equipment was operated between the points of material supply and the job,in the exclusive service of the contractor owning it. In order to prevent loss of this equipment, or divertion at a junction point, a man or two was generally assigned to the task of keeping track of it. The railroad charged a certain amount for hauling material in this manner, and reimbursed the contractor for the use of his equipment at the rate of about $0.006 per mile.

A notable example of the use of privately owned standard railroad equipment in highway construction, was afforded by the Crittenden-Ozark road project in Arkansas in 1920. The equipment consisted of 105 Western air dump cars of 30 cubic yard capacity, which was operated from the gravel pit at Wittenberg, Missouri, over the Frisco Railroad a distance of 170 miles to the job. At the unloading point material was dumped on each side of the track, which was jacked up from time to time so as to form a large embankment of gravel. This embankment at one unloading point was 800 feet long and from 20 to 30 feet high at the highest point. The track was shifted and material unloaded by a gang of 14 men and 1 foreman, at a contract price of $0.20 per ton. Previous to adopting the embankment system, an Erie crane equipped with a 3/4 yard clam shell bucket was used for unloading material at a cost of $0.30 per ton. The saving in the cost of unloading the 287,400 tons of gravel, was thus considerable. The loaded cars were run in solid trains of 30 cars, each containing about 37 tons of material. The railroad charged $50.00 per loaded car for hauling, and returned the empty cars free of charge in mixed trains. The road district received the rental of $0.006 per mile from the railroad for the use of their equipment. Loaded trains left the gravel pit at Wittenberg at 6 o'clock in the evening, and arrived at Chaffee, a junction point 30 miles from Wittenberg, at midnight. At 9 or 10 o'clock the following morning, the loaded train was at the job. The work of switching and dumping the train of 30 cars required about 2 hours. The round trip of 170 miles, including switching, dumping, and loading, required 3 days. During the last week of November, 1920, 217 cars were unloaded. The Morgan Engineering Company, of Memphis, Tenn. were in charge of this project, while the Industrial Track Construction Company, of St. Louis, Missouri, shifted the track and dumped the cars for a contract price of $0.20 per ton. The cost of the air dump cars was somewhat over $300,000, and it is questionable whether the saving effected by this system is sufficient to compensate for the loss when these cars are sold as second hand. If this method had not been adopted, however, all work in this road district would have been suspended due to the inability to secure materials.

The question of whether a contractor is justified in purchasing standard railroad equipment, is one which demands careful study. If such equipment can be operated long enough to take advantage of its low rate of depreciation, not exceeding 10 per cent per year, privately owned standard railroad equipment will probably prove economical. Even though the actual cost of hauling on some particular job is increased due to privately owned railroad equipment, a contractor might be justified in purchasing such equipment because of the greater reliability of material supply. It is the cost of such intangible factors as uncertainty of material supply, which ruin contractors more often than the increased cost of some definite operation such as unloading or hauling material. Men who have had experience in Europe claim that it is quite the common thing there for a contractor to own his own railroad equipment. Probably as road work is organized on a greater scale and large road building organizations are formed, the practice of owning standard railroad equipment will come into more general use. Particularly is this true of railroad contractors who enter the highway construction field, inasmuch as they generally possess standard gauge, large capacity, earth moving equipment which can be adapted to hauling material for highway construction.

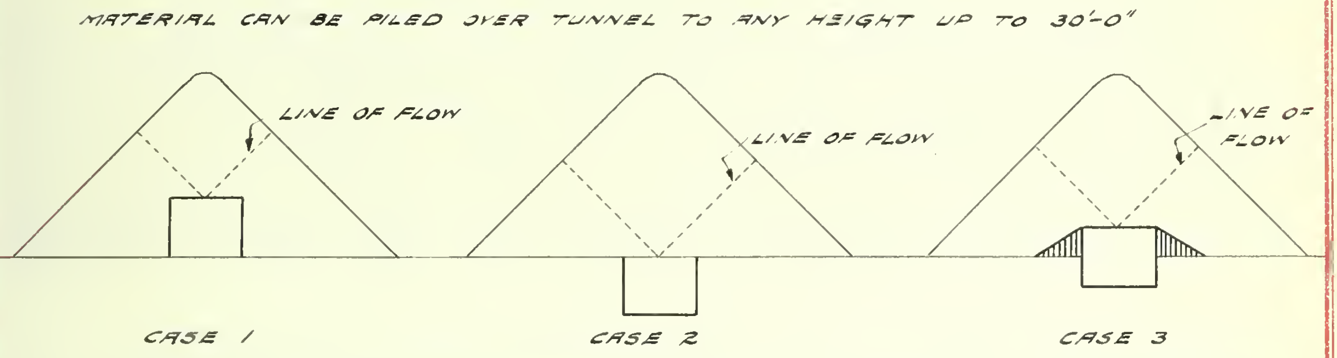
When road building material is stored in quantity at unloading points, the problem is to store the maximum amount of material on the minimum amount of space, which is frequently limited, and to rehandle the material most economically. The problem of rehandling material is a very important one, and is one to which many contractors do not give proper consideration. The rehandling of material is often very troublesome and expensive, and close attention should be paid to this problem.

The method of storing material over a tunnel constructed of wood frames and sheeting has come into quite general use during the past two years, and is recognized as one of the best on account of the ease and economy with which materials are rehandled. Traps are placed in the roof of the tunnel approximately 8 feet apart, or every car length, thru which material can be charged into light railway cars. Due to the large amount of head room required, the tunnel system is impractical for loading any other type of haulage equipment than light railway. The tunnel system of storage provides the maximum amount of storage per unit of area occupied. A considerable proportion of the material piled over a tunnel will flow thru the trap by gravity, and continuous operation of the concrete mixing plant is thus assured in spite of temporary breakdowns of the unloading equipment. This is one of the biggest advantages of the tunnel system of storage. Continuous operation of the concrete mixing plant is also insured in spite of temporary delay in railroad shipments.

PORTAL VIEW OF MATERIAL TUNNEL

SIDE VIEW OF MATERIAL TUNNEL

Material storage tunnels can be classed under three general heads, namely, the tunnel entirely above ground, the tunnel entirely below ground, and the tunnel half below and half above. These three general methods are shown in the sketch below.



A material yard must sometimes be placed on a piece of rented ground where it is undesirable to excavate a trench for the tunnel, or the presence of rock or ground water may prevent sinking the tunnel. In such a case the tunnel must be placed above ground, as shown in case #1 above. Assuming a slope of 1 to 1 for the material, 25 per cent of the material will flow by gravity as shown by the dotted line. It is necessary to rehandle the remainder, and this must generally be done by means of a crane and a clam shell bucket. The problem of rehandling should be eliminated if possible, by adopting one of the other methods shown.

Case #2 shows a tunnel entirely below ground. Assuming slopes of 1 to 1 for the material, 50 per cent will flow by gravity as shown by the dotted line. The remainder of the material can easily be rehandled by dragging it over the tunnel by means of teams and scrapers, or by means of a small gasolene engine and a power scraper. From the standpoint of rehandling, the tunnel entirely below ground is to be preferred. It is also obvious that a smaller amount of material must be rehandled when the tunnel is placed below ground, than with either of the other methods. It is possible, therefore, to operate for a greater length of time in case of a breakdown of the unloading equipment, than with either of the other methods. Many contractors prefer placing the tunnel entirely below ground even though the cost of so doing is considerably greater than that of the other two methods, and even though a pump must be installed for handling ground water.

Case #3, with the tunnel partly below and partly above ground, is a method which is most generally used. In this method the material excavated from the trench is banked against the side of the tunnel, as shown by the cross-hatching, so as to make the problem of refilling the trench an easy one. With a tunnel of this kind, 37 per cent of the material will flow by gravity. Due to the sloping earth banked the outside, the problem of rehandling material is practically no more difficult than where the tunnel is placed entirely below ground.

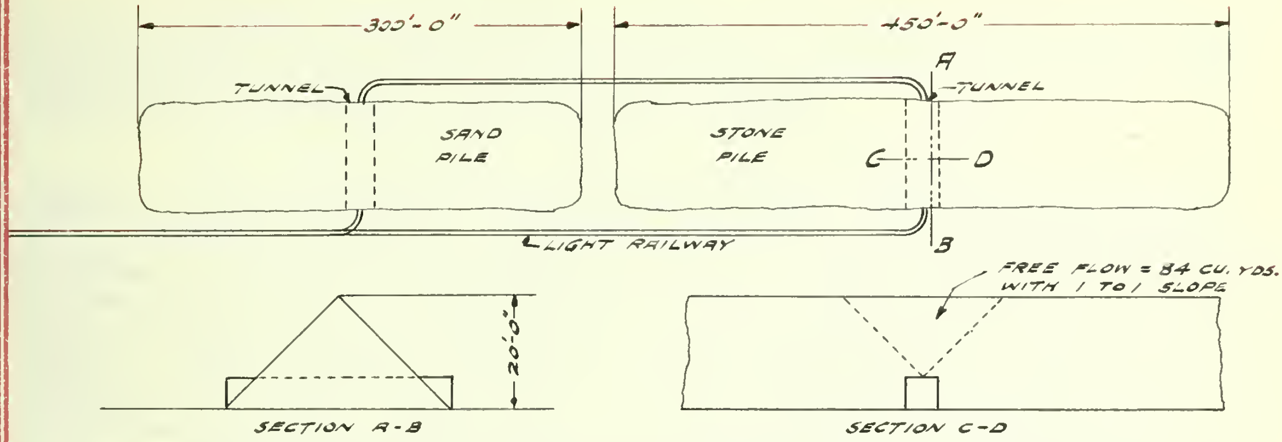
The quantity of material which can be stored by the tunnel method depends upon the length of the tunnel and upon the height to which material can be piled. The height to which material can be piled depends, in turn, upon the length of boom of the unloading crane or derrick. Data sheets showing the detail of design of tunnels and their storage capacity, will be found in the appendix.

The cost of a material storage tunnel depends, of course, upon the cost of lumber and the cost of labor. Tunnels have been constructed of old railroad ties and of timber cut down by the contractor in clearing the right of way. Such tunnels were very moderate in cost. As a rule, where dimensioned lumber is used at a cost of about $60.00 per thousand feet board measure and carpenter labor cost about $1.00 per hour, a tunnel build according to the design in the appendix, will cost about $10.00 per lineal foot in place. This is exclusive of the cost of grading, and is based upon a cost of about $25.00 to $30.00 per thousand feet board measure for fabricating. As shown by the design, the tunnel is so constructed that it can be knocked down and moved from one job to another. The use of structural steel frames in a tunnel has been proposed and has been given considerable thought, but to date wood has been exclusively used in building tunnels except in one case where steel "I" beams supported the roof. Tunnel traps costing $23.50 each in March, 1921, must be placed in the roof of the tunnel every 8 feet. The final cost of the tunnel, therefore, is about $13.00 per foot.

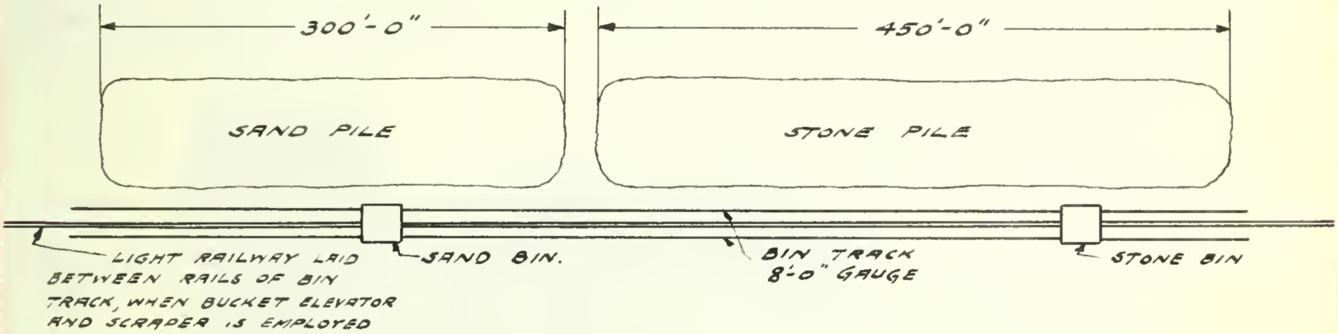
Where a large amount of material is to be stored during the inactive road building months, the tunnel system becomes very expensive. Due to the limited reach of the boom on the unloading crane, it is necessary to place material in a long pile. A concrete road 18 feet wide, of a 1-2-3 mixture, and 7-1/3 inches average thickness, requires 1,120 cubic yards of sand and 1,680 cubic yards of stone per mile, or a total of 2,800 cubic yards of material. A crane with a 45 foot boom equipped with a 3/4 cubic yard clam shell bucket, can pile material to a height of about 20 feet. Assuming a 1 to 1 slope for the material, such a pile will contain about 15 cubic yards per lineal foot. A pile 187 feet long is, therefore, required to store sufficient material for 1 mile of road, while a pile 750 feet long is required to store material for 4 miles of road. Obviously a tunnel, at $13.00 per lineal foot, would be very expensive in this case.

LONG MATERIAL STORAGE PILE

In order to eliminate the expense of placing a tunnel thruout the entire length of a long pile of material, the use of short cross tunnels has been suggested. These tunnels would be placed crosswise of the material pile as shown in the following sketch. A small percentage of material would flow by gravity, and the remainder could be rehandled by means of a light drag line, or preferably by means of a hoisting engine and a line attached to a scraper.



Another method of rehandling material where it is stored in a long pile is by means of small movable bins operating on tracks the entire length of the pile. This method is illustrated by means of the following sketch and photograph.



MOVABLE BIN REHANDLING PLANT

The movable bin illustrated above, operates on a track of about 8 foot gauge. Material can be loaded into the bin by means of a crane and clam shell

bucket, as shown in the photograph, a bucket elevator and a power scraper, or a portable bucket loader such as that illustrated on page 5. The crane in the photograph shown above is an Erie steam shovel equipped with a 30 foot boom. Strips of steel bolted on the wheels form flanges.

When movable bins are used they are sometimes placed on a flat car, the sand bin on one car and the stone bin on the other. The locomotive crane is placed between the cars and operates back and forth along the material pile. With a system of this kind it is necessary to lay the light railway track to one side of the bin track, and to charge the batch boxes by means of side gates in the bin. Another method consists of operating the crane between bins, which occupy more or less of a fixed position. Where the material pile is long, however, one crane might not suffice for this purpose. If power scrapers are used, a small gasolene engine can be mounted beneath each bin for the purpose of dragging material up to the bucket elevator. This engine can also be used for moving the bins, by means of a line attached to a "dead man". Teams and drag scrapers might be used for dragging material to the bucket elevator, but this method is more expensive than the power scraper method. When the bucket elevator and power scraper method is used, it is possible to lay the light railway between the rails of the bin track and operate the batch box cars underneath the bin. The photograph below illustrates this method.

LIGHT RAILWAY TRACK IN CENTER OF MOVABLE BIN TRACK

Instead of using movable bins, two or more small stationary bins are sometimes used. In this case the locomotive crane operates between the material pile and the bin. Obviously with this system it is not feasible to store material in a very long pile. The movable bin method is to be preferred to the stationary bin method.

The movable bin method of rehandling material is quite commonly used where material is to be stored in large quantities. With this method it is possible to release the unloading crane for duty at some other unloading point, as soon as sufficient material has been stored at the point in question. The movable bin method is perhaps the best method of rehandling large quantities of material.

SMALL STATIONARY BIN REHANDLING PLANT

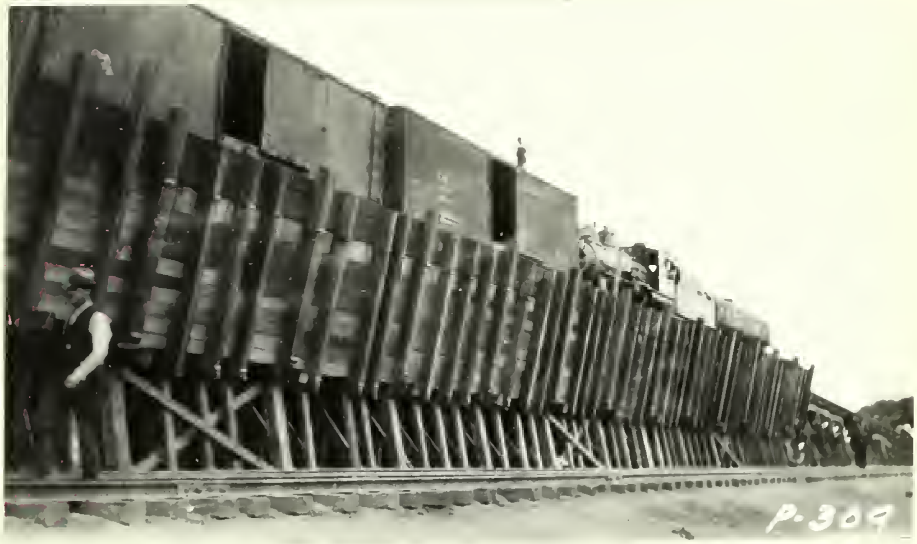
In hilly country, it is frequently possible to build a trestle thru which material can be dumped from bottom dump cars onto a pile or tunnel below. This method of operation requires bottom dump cars, which might be difficult to secure in certain parts of the country. If it is necessary to construct any considerable amount of trestle, this method might become quite expensive. The cost of building the trestle, however, would be offset somewhat by the decreased cost of unloading and by the elimination of an unloading crane. Whether these factors are sufficient to justify the use of the trestle method depends upon local conditions.

SMALL MATERIAL DUMPING TRESTLE

In level country a material dumping trestle might be used when bottom dump cars are available, but the cost in such a locality would probably be greater than in hilly country. The trestle method of unloading material has been used in level country, where the size of the job was sufficient to warrant the investment.

A notable example of the use of a trestle for unloading purposes in level country, is that of Twohy Brothers, of Portland, Oregon, on their 288 mile concrete road contract in Maricopa County, Arizona. This trestle, illustrated in the photographs below, was built according to the standards of the Southern Pacific Railroad, with proper modification to permit a bunker to be suspended underneath. The approach is on a 4 per cent grade, and a light railway track runs underneath the trestle. This trestle has a storage capacity of about 2,500 cubic yards of material, and cost $20,000. It can be dismantled, and set up in another location.

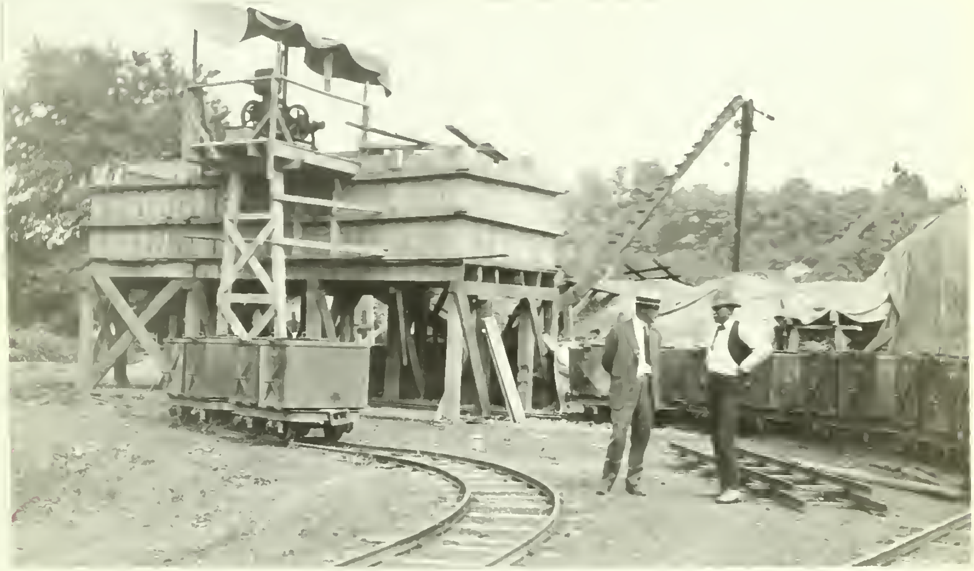
TRESTLE SYSTEM OF UNLOADING MATERIAL



A material trestle, such as that illustrated above, is obviously too expensive for anything but a large job. Unloading equipment is entirely eliminated, however. Material, once placed in the bunker, is loaded into light railway cars by means of gravity, so the problem of rehandling need not be considered.

One of the most common methods of storing and rehandling material, is the stock pile and bin method. A derrick is generally used for unloading material, which is placed in large piles near the bin. The objection to this method is the

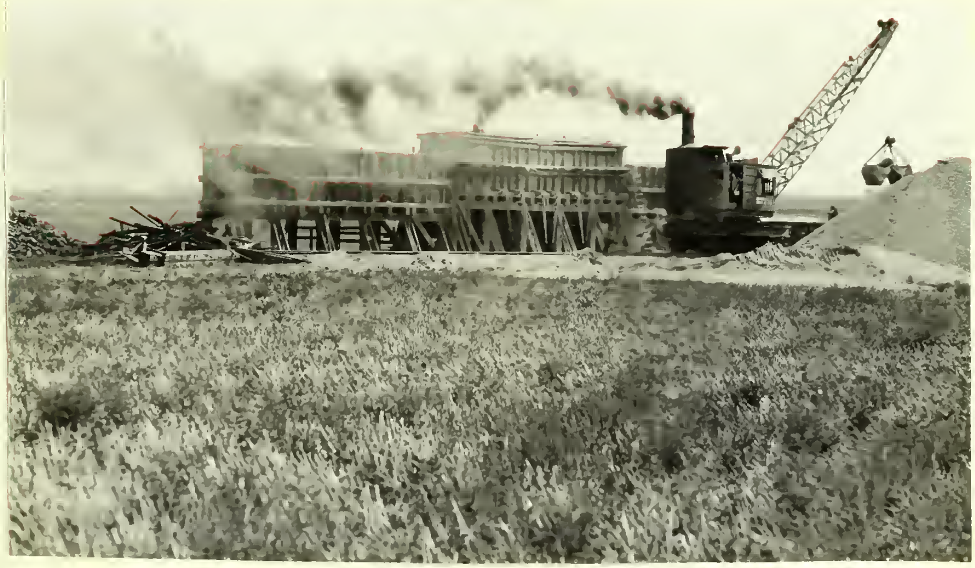
restricted amount of storage possible, on account of the limited reach of the boom of the derrick or crane. A derrick with a 60 foot boom and a 3/4 yard clam shell bucket, can pile material to a height of about 30 feet. Such a pile, which is generally conical with a 1 to 1 slope, will contain about 1,000 cubic yards of material, and two such piles are all that one derrick can reach. The quantity of material stored, therefore, is not sufficient to construct one mile of 18 foot concrete road.



STOCK PILE AND BIN METHOD OF HANDLING MATERIAL

Another objection to the method described above, is due to the inability of the derrick to reach the material at the far side of the pile. It is generally necessary, therefore, to use a line from the hoisting engine to a power scraper, for the purpose of dragging the material to the point where the derrick can reach it. On account of the limited storage capacity of the bins generally employed with this type of unloading plant, a breakdown of the derrick would cause a shut down of the concrete mixer. To provide for only one day's operation of a 14-E mixing plant, will require a bin of about 200 cubic yards capacity. A large bin, such as that illustrated in the photograph on the following page, is very expensive. Rather than use a bin, it would seem to be preferable to place a short tunnel underneath the pile of material, as illustrated on the next page.

The type of derrick most commonly used is the stiff leg type, though, where conditions permit, guy derricks are often used. Derricks are generally fixed in position and can unload from but one car at a time, so it is necessary to "spot" each individual car. Traveling derricks are sometimes used, but these outfits are very cumbersome and almost as expensive as a crane. A derrick of any type is much more cumbersome and slow than is a crane, but where a contractor already possesses derrick equipment it is probably more economical for him to use it, at least temporarily, than it is to purchase a crane. When a derrick is used for unloading purposes it is desirable that the boom be at least 60 feet long. A long boom is also desirable on a crane, for the longer the boom the greater the amount of material that can be stored.

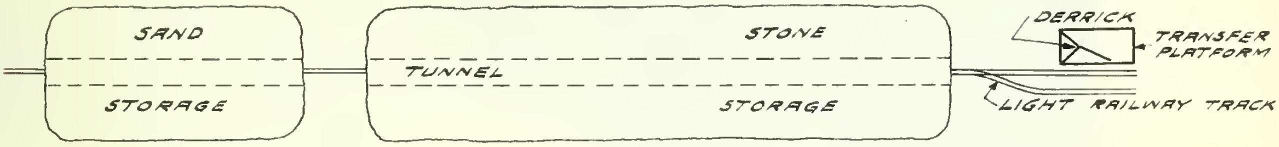


LARGE MATERIAL STORAGE BIN

TUNNELS BENEATH PILES STORED BY DERRICK

When a combined light railway and motor truck haulage plant is used, it is impractical to build a tunnel large enough to permit the trucks to pass thru. Bins are generally used with this type of plant, but the tunnel system of storage can be employed by operating platform cars thru the tunnel on a short stretch of track. Each car will carry 4 batch boxes, and these batch boxes will be transferred to motor trucks at the entrance to the tunnel. The cars can be pushed thru the tunnel by hand by two men if there are no grades, or a small hoisting engine can be used for this purpose. A light derrick can be placed on the transfer platform, for transferring batch boxes from car to platform to truck. Another method of transferring batch boxes,consists of carrying all 4 boxes on a frame. This frame is equipped with wheels, so that it can be rolled from the car to the platform to the truck. In order to place the truck body on the same level with the platform, it is generally necessary to excavate a pit into which the trucks can run. A small hand winch and a light line, will furnish power for moving these

frames. With this plan of operation it is necessary to have a frame for each truck, a frame for each of the two platform cars, and several extra frames to permit the storage of loaded frames on the platform. A shuttle system of two platform cars carrying 4 batch boxes each, operated by 4 men, is sufficient to supply batch boxes to the transfer platform at the rate of 30 per hour when the length of the tunnel does not exceed 300 feet. The layout of a plant such as that just described, is shown in the sketch below.



The material unloading device commonly employed on small jobs, consists of a portable bin equipped with an elevating skip or a bucket elevator. Such a bin has a capacity of about 50 tons of material at the most, and its successful operation depends upon day to day delivery of material by the railroad. Inasmuch as no storage is provided, the lack of insurance against delay due to erratic railroad delivery is obvious. A bin of this type of 50 ton capacity costs about $1,800.00. The Galion Iron Works, of Galion, Ohio, and the Sunbury Manufacturing Company, of Sunbury, Ohio, manufacture typical bins of this class.

THE SUNBURY UNLOADER

The bucket elevator system of unloading material is sometimes used in conjunction with bins of considerable capacity, say 50 to 75 cubic yards. With this system of unloading, it is necessary to "spot" each car accurately over the pit which it is necessary to excavate beneath the railroad track. From this pit material is fed to the bucket elevator by means of a gate. The bucket elevator system provides no storage capacity outside of that in the bin itself. A bin of this size, illustrated in the following photograph, is quite expensive. This system of unloading is not recommended for any but very small jobs.

BIN AND BUCKET ELEVATOR SYSTEM

The most common method of handling cement at the present time is the bag method, each bag containing 94 pounds or about 1 cubic foot of cement. Bagged cement is generally stored in a shed, and the bags are either emptied directly into the cement compartments of the batch boxes or into small hoppers. These hoppers contain sufficient cement for one batch. When light railway haulage is used a long platform is generally provided alongside the cement storage shed. The train passes alongside this platform, or underneath, and takes on the proper amount of cement from each hopper. The photograph on page 75 shows the cement platform along the cement house, which is placed at one end of the material tunnel.

Bagged cement is generally unloaded from cars into the cement shed or onto the cement platform by hand, though sometimes belt conveyors are used. The cement platform is generally placed at the same height as the car floor, so that hand trucks can be used for handling cement. The photograph below illustrates the method of handling bagged cement by means of hand trucks. The men in the foreground are engaged in dumping cement into small hoppers, which discharge into the light railway cars operating beneath the platform.

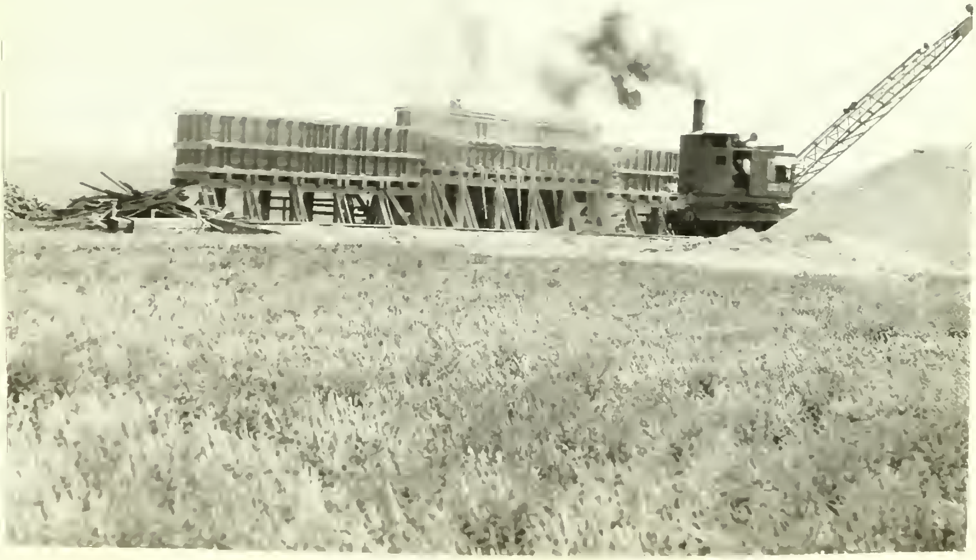
METHOD OF HANDLING BAGGED CEMENT

The principal objection to placing cement in bags, is the added investment of $1.00 per barrel required by the cement companies for the bags. Of course, this money is refunded when the sacks are returned, but meanwhile a considerable amount of working capital has been invested in a non-productive item. Many bags are lost or torn or are wet, so that the contractor receives no credit for them from the cement company. Experience indicates that the average cement bag is good for about 8 trips, so that a contractor should figure on ultimately paying for 1 bag out of every 8. He might, perchance, have the good fortune to receive all good bags for a while, but if he stays in business for more than a year or two he will surely receive his proportionate share of worn out bags. The cost of unloading and handling bagged cement is somewhat greater than that of bulk cement, while the price charged by the cement companies is $0.05 per barrel greater than for bulk cement. During the past two years the practice of using bulk cement has become quite general.

When bulk cement was first used in highway construction, in 1914, it was shipped in box cars, and was unloaded by means of wheeled scoops directly into wagons. The cement was hauled in these wagons and unloaded into weather tight boxes, spaced at intervals along the road, by means of scoop shovels and coal shutes. From these boxes the cement was shoveled into wheelbarrows, and handled in the same manner as sand and stone.

At the present time bulk cement is frequently shipped in open top cars, and is protected from the weather by means of a tarpaulin supported on light wooden frames. The cement company charges for this tarpaulin in the same manner as for cement bags, and reimburses the contractor when the tarpaulin is returned. Several instances are known where the tarpaulin was removed by someone, and the cement exposed to the elements. One such car after passing thru three heavy rains was found to contain a 6 inch crust, beneath which the cement was perfectly good. The cement was so well protected by this crust, that it was even proposed to do away with tarpaulins altogether and to sprinkle the cement in order to form a crust.

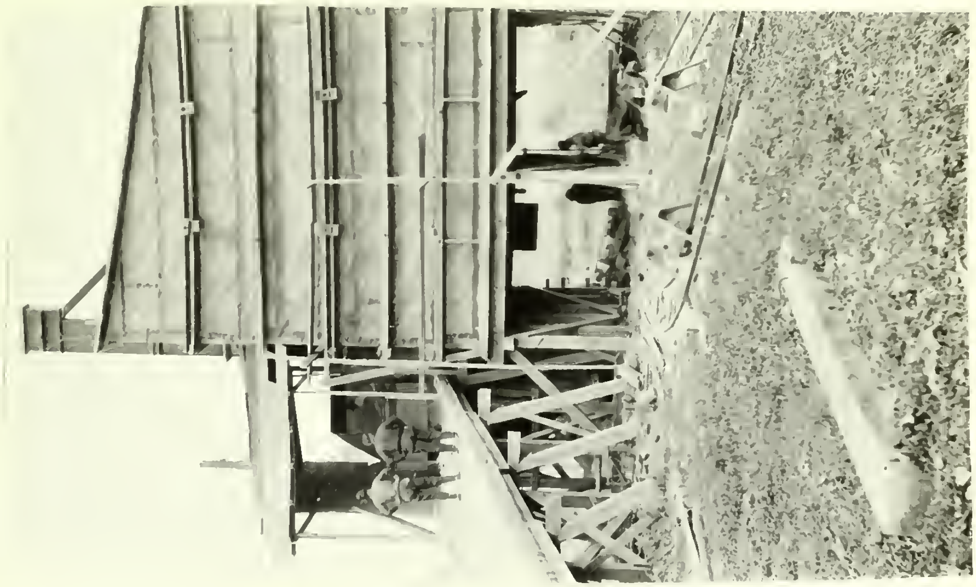
When bulk cement is shipped in open top cars it can be unloaded by means of a clam shell bucket in the same manner as sand and stone, and placed in a bin thru hatches in the roof. Cement is loaded into the light railway train in the same manner as sand and stone.



BULK CEMENT BIN BETWEEN SAND AND STONE BINS

Bulk cement shipped in box cars is handled by a number of methods. One method is to construct a large box or bin at the car door, of sufficient capacity to hold one or more cars of cement. The cement can be unloaded into this bin by means of a power scraper or wheeled scoops. During the noon hour or at the end of the day, the crane can transfer the cement from the temporary bin into the permanent bin by means of a clam shell bucket. Another method of unloading cement in bulk from box cars, is by means of a portable belt conveyor such as that manufactured by the Barber-Green Company, of Aurora, Illinois. One end of this conveyor is placed on top of the bin so as to discharge into a hatch, and the other in the box car. Cement is shoveled onto the conveyor by means of scoop shovels. In order to prevent the blowing away of cement, it is wise to surround the belt conveyor with a canvas covering supported on a light wooden frame. The best method of unloading bulk cement from box cars, is by means of a power scraper such as that used in unloading grain. The cement is scraped into a hopper at the door of the car, from which it is fed to a bucket elevator which carries it into a bin.

A particular job comes to mind at this time, on which bulk cement was received in box cars at a railroad siding 6 miles from the job. The cement was unloaded into a thousand barrel bin at the railroad siding by means of the power scraper and bucket elevator system. Motor trucks carried the cement from the bin at the railroad siding up an incline to a bin near the job. The trucks dumped the cement into a hopper, from which it was fed to a bucket elevator and placed in a 2,000 barrel bin. Light railway cars, on their way from the gravel pit to the job, passed beneath this bin and took on the proper amount of cement. The photograph below shows this method of handling bulk cement.



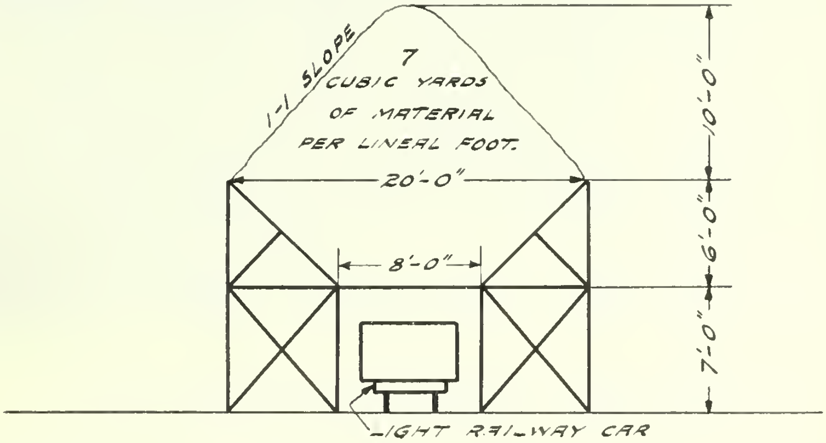
HANDLING BULK CEMENT BY MOTOR TRUCK

Cement companies claim that bulk cement will effect a saving of $0.25 per barrel over bagged cement. When proper charges are made for handling equipment, bins, etc. it is not believed that the net saving will exceed $0.15 per barrel. This saving, however, is sufficient to warrant a contractor giving serious consideration to the use of bulk cement. During the car shortage prevailing the past two years, it was generally much easier to secure shipments of bulk cement than of cement in bags.

The trestle system of unloading material is well adapted to the handling of bulk cement, for it would seem to be entirely feasible to ship bulk cement in bottom dump cars and dump directly into the bunker underneath the trestle thru hatches. In case bulk cement is shipped in box cars, a power scraper could be used to scrape the cement directly into the bunker thru small hoppers.

Bulk cement storage bins are more expensive than storage sheds for bagged cement. In general a bulk cement bin will cost about $400.00 to $500.00 per car of capacity, whereas a good cement shed will not cost more than about one-fourth of this amount.

Sometimes it is desired to employ a method of storing material which possesses greater capacity than the ordinary bin method, in a location where, for some reason or other, it is not desired to use a tunnel. In such a case the so-called bunker method will frequently meet the requirements. The sketch below illustrates the general features of this method.



It is apparent that material can be heaped up on a bunker after it is level full, so as to obtain almost as much storage capacity as a tunnel placed above ground. Furthermore material need not be rehandled, when once placed in the bunker. The bunker method does not require much more timber than the tunnel method, and, considering its greater storage capacity, it requires less timber than a bin. It is highly desirable for a contractor to store the largest amount of material possible, and on those jobs where it is impractical to use a tunnel and a storage capacity greater than that afforded by bins is desired, the bunker method might prove suitable.

In laying out a material yard, it is desirable that bins or tunnels be so arranged that the process of loading is a continuous one and no doubling back is required. Cement storage sheds or bins are, therefore, generally placed in direct line with the material tunnel. It is also desirable to arrange the layout so that when bagged cement is used, it can be unloaded directly into batch boxes carried on railway cars or trucks, as illustrated on page 65. Such an arrangement largely eliminates the cost of rehandling cement from the shed to the batch boxes. As a rule the cost of unloading bagged cement into a shed is about $0.10 per barrel, with labor at about $4.00 per 10 hour day, and the cost of rehandling cement to the batch boxes is about the same. When the material yard is so arranged as to permit unloading directly into batch boxes, the saving per barrel is approximately $0.10. The method of direct charging of batch boxes from the cement cars, should of course not be used unless plenty of track room is available or if it entails excessive demurrage charges.

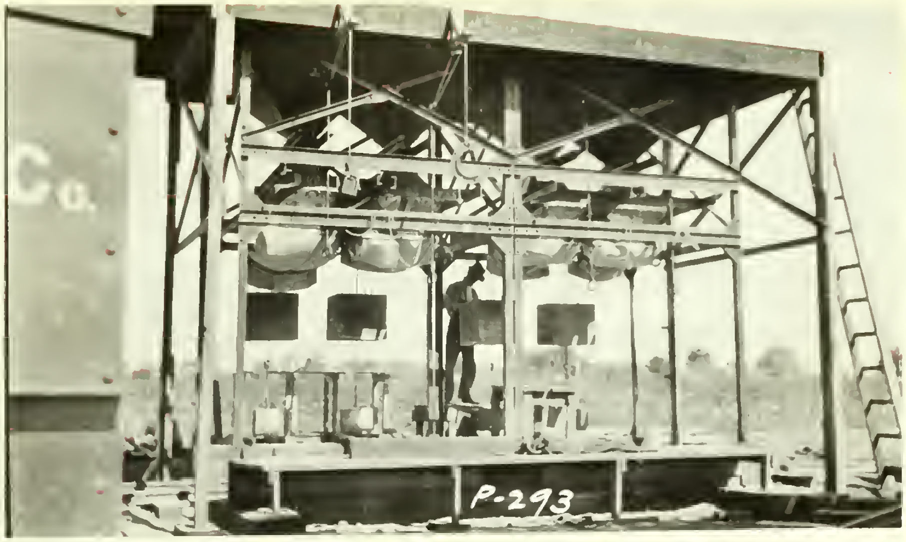
When bagged cement is used the problem of measuring the cement has already been taken care of by the cement manufacturer, for each 94 pound bag is almost universally accepted as containing 1 cubic foot of cement. When bulk cement is used, however, a method of measuring must be devised by the contractor. One cubic foot of loose cement seldom weighs 94 pounds, on account of the "fluffing" of the cement. For this reason most engineers now require that bulk cement be measured by weight. When volumetric measurement of bulk cement is permitted, an efficient and rapid method is shown in the photograph below.

VOLUMETRIC METHOD OF MEASURING BULK CEMENT

Cement is measured in the method illustrated above, by means of two sliding gates operating on the same lever arm. The volume of the measuring shaft between these two gates is just sufficient to provide cement for one batch. Some difficulty was experienced at first in cutting the stream of cement at the upper gate, thru the full 15 inch cross section of the shaft. The difficulty was eliminated by inserting a small hopper arrangement in the measuring shaft just above the upper gate, so that the stream of cement could be reduced to a 6 inch cross section.

When bulk cement is measured by weight, one cubic foot is assumed to weigh 94 pounds. It is not a difficult matter to devise a weighing device to measure bulk cement. A number of devices for weighing grain are on the market, but these are generally too expensive for the purpose of weighing cement and they do not give better results than a home-made device. A bulk cement weighing device manufactured by The Lakewood Engineering Company, of Cleveland, Ohio, for use on large installations, is shown in the photograph on the following page.

In order to prevent dusting when charging batch boxes with bulk cement, a canvas tube should be provided. This tube leads from the cement measuring device, and can be tucked into the cement compartment of a batch box. Not only does this tube prevent dusting, but it enables a car to be loaded even though it is not accurately spotted.



BULK CEMENT WEIGHING DEVICE

A problem with which a contractor is frequently confronted, is that of deciding whether to utilize existing side tracks for unloading purposes or to build a private siding. Existing sidings frequently are not located advantageously with respect to the job, and they must often be shared with other interests. When a contractor builds his own siding he is generally assured of exclusive use of it, and the inconvenience and delay resulting from the joint use of a siding with other interests is thus avoided. It is also possible for him to so locate his sidings, as to reduce his ton mileage very considerably. Whether the factors of decreased ton mileage due to proper location of siding, and smaller chance of delay due to a private siding, are sufficient to warrant the cost of building a private siding, can only be determined after proper consideration of all factors.

When light railway haulage is used unloading sidings can be located almost anywhere, because light railway track can be laid thru or around the edge of fields, up ravines, around the side of hills, etc. In other words with light railway haulage, the location of unloading sidings is not limited by existing roads. This enables sidings to be so located as to reduce ton mileage to a minimum. With any method of haulage other than light railway, on the other hand, it is generally necessary to either utilize existing sidings, or to locate new ones near existing roads. The resulting location due to the necessity of considering existing roads, might be such that the reduction in ton mileage is insufficient to compensate for the cost of the siding. A private siding is always desirable, however, and frequently the lessened chances of delay incident to the use of a private siding will alone justify its construction.

Sometimes a number of unloading sidings are available. The problem then is to determine how many of these sidings to use. By using all of them the ton mileage and the amount of equipment required would probably be reduced, but the delay due to moving from one location to another might be very serious. Here again, judgment and experience must be exercised in deciding upon the plan of operation. In general it will not profit a contractor to establish so many unloading points, that the delay in moving from one to the other will leave him with unfinished work to be carried over to the following year. The possibility of loss due to carrying over work to the following year, is frequently so great as to justify a considerable increase in the ton mileage due to using fewer unloading points. The proper method is to use the fewest possible unloading points consistent with a fairly low ton mileage, in order to reduce delay due to moving unloading points to a minimum. The general method of procedure in deciding upon the number of unloading points to use, is to compare the cost of installing and operating the

additional unloading point with the saving due to decreased ton mileage and the cost of delay caused by moving.

Many contractors consider the delay of two weeks to one month in dismantling a material yard at one point and installing it at another, to be so serious, coming as it does in the height of the construction season, that they make every effort to so arrange a job as not to require moving the material yard. Some contractors will bid only on such jobs as can be handled from one material yard, and only on such jobs as they can finish in one season. If they bid on longer jobs they so arrange the work as to permit the unloading point to be moved in the winter time.

The central unloading and proportioning yard featured in modern highway construction not only lends itself readily to the use of bulk cement and to economy in bags in case of bagged cement, but it is especially adapted to storing material in the winter time. Most states which make provision for monthly payments on material stored during the winter time, require that the material be stored in large piles near a railroad. The central unloading and proportioning yard, therefore, is in accordance with state highway specifications, and insures maximum payments on material stored during the winter time.

The type of unloading equipment to use, depends largely on the type of railroad cars in which material is received. In many parts of the country hopper bottom cars prevail, and in such a case a pit can be excavated beneath the track and material discharged directly into a bucket elevator. In order to secure greater capacity and range of distribution than is provided by the bucket elevator, derricks or cranes equipped with clam shell buckets are much used. In case material is received in hopper bottom cars, a pit is excavated to one side of the track into which material can be discharged from a sloping pit underneath the track. Material is then picked up from the pit by means of the clam shell bucket. If the job is large enough to warrant it, a trestle might be used thru which material could be dumped into a bunker.

Undoubtedly the best type of unloading apparatus at the present time is a traction crane either of the flanged wheel or caterpillar type. Such a crane equipped with a clam shell bucket, can move up and down the siding and unload material anywhere in a long pile. A light steam shovel equipped with a 30 to 35 foot boom, can handle a 3/4 yard clam shell bucket. Such a shovel so equipped will cost about $10,000 at the present time, and is a very good piece of apparatus for unloading purposes. In selecting unloading equipment, it is important that a long boom be obtained.

Experience indicates that a 3/4 yard clam shell bucket is the best all around size for unloading material from railroad cars. A larger size might pick up more material the first few times, but after that the larger bucket would not take a bigger load than a 3/4 yard. The increased time required to "spot" the larger bucket, also tends to reduce its output.

A good operator on a derrick with a 50 or 60 foot boom and a 3/4 yard clam shell bucket, should unload from 8 to 10 carloads of material of 35 cubic yards each in 10 hours. A good operator on a crane should unload from 10 to 12 carloads under the same conditions.

When bulk cement is shipped in open top cars and is unloaded by means of a crane and clam shell bucket into a bin, about 17 per cent of the time of the crane is required for handling the cement.

CHAPTER XI.

PERSONNEL REQUIRED.

The personnel required in highway construction naturally varies with the size of the job and with the type of equipment employed, as well as with the efficiency and organizing ability of the contractor. In comparing the personnel required by various methods of road building, we will assume a concrete road 18 feet wide, and 7-1/3 inches in average thickness. A 14-E mixer handling a 4 bag batch of 1-2-3 concrete, will constitute the mixing plant.

Unloading material by hand from railroad cars onto the ground, is but seldom practiced in highway construction today. Even small contractors on small jobs generally employ some mechanical or semi-mechanical means.

In order to eliminate hand shovelers an "A" frame is sometimes erected on one side the car. A cable passed thru a sheave attached to the "A" frame is fastened to an ordinary drag scraper, and material is scraped out of the car onto the ground or into a side hopper. Power for operating this scraper is furnished by means of a team or a small gas engine.

To reduce the waiting time of haulage equipment at the material yard to a minimum, is a problem to which contractors have always devoted a good deal of attention. One of the first methods of accomplishing this was by means of hoppers attached to the side of the car. Material was shoveled by hand into these hoppers, each of which contained one wagon load of material. A typical hopper of this type is that which is known as the Heltzel Lightning Unloader, manufactured by the Heltzel Steel Form & Iron Company, of Warren, Ohio.

Movable hoppers have been used, into which material is unloaded by means of a light crane or derrick. The photograph below illustrates hoppers of this type.

MOVABLE MATERIAL HOPPERS, ONE LOAD CAPACITY

A portable wooden bin equipped with a bucket elevator or an elevating skip, is a type of unloading apparatus very commonly used at the present time on small jobs. A typical bin of this kind is illustrated by the photograph on page 82. A derrick or a crane equipped with a clam shell bucket, is the most commonly used type of equipment for unloading material for highway construction.

In unloading material by hand onto the ground or into hoppers attached to the side of the car, a fair rate of operation is about 20 cubic yards of sand or 15 cubic yards of stone per man per 10 hour day. If cement is unloaded directly from the railroad car into a truck or wagon, from 3 to 4 men will handle about 300 barrels of cement per day. The cement men, added to the 6 sand shovelers and 12 stone shovelers necessary in unloading sufficient material to supply a 14-E paving mixer laying 400 feet of 18 foot concrete road per day, makes a total of about 22 men. A foreman and a water boy should be added to this organization.

In unloading material by means of the drag scraper method, it is necessary to provide a scraper and an "A" frame for sand and one for stone. One man will be required to operate the scraper, and about 3 more to clean material out of the corners of the car. A driver for the team or an operator for the hoisting engine used to provide power for the scraper, must also be provided.

Three to 4 men will be required when a portable bin with a bucket elevator, or an elevating skip, is used for unloading purposes, in addition to an operator for the gasolene engine. These men are needed to clean out cars, feed the elevator or bucket, and to shift cars.

The methods of unloading material described in the preceding paragraphs, except the derrick or crane method, are not suitable for highway construction on a large scale, and are mentioned only as a matter of general interest.

In determining the personnel required by various methods of road building, we will assume an 8 mile concrete road, 18 feet wide, with an unloading point at the center. Five methods of road building will be considered, namely, team or truck haulage with material dumped on the subgrade and charged into the mixer by hand, direct charging of the mixer by means of a 5 ton motor truck with compartment dump body, direct charging of the mixer by means of a Ford truck with special dump body, the combined light railway and motor truck system, and the complete railway system. The daily output will be taken at 400 lineal feet of 18 foot concrete road of a 1-2-3 mixture, averaging 7-1/3 inches in thickness.

The quantities required are as follows:

	PER DAY	TOTAL
Cement	285 bbls. or 54 tons	30,160 bbls. or 5670 tons
Sand	85 cu.yds. or 128 tons	8,962 cu.yds. or 13442 tons
Stone	128 cu.yds. or 355 tons	13,442 cu.yds. or 18147 tons

A light steam shovel such as the Erie or the Thew, equipped with a 30 or 35 foot boom, caterpillar traction, and 3/4 yard clam shell bucket, will form the unloading equipment. The tunnel system of storing material will be used with the complete railway plant, and the stock pile and bin method with the other plants.

The road we have under consideration will require 3,016 loads of cement, 5,975 loads of sand, and 8,963 loads of stone. This is based on an average

load for a team of 10 barrels of cement, 1-1/2 cubic yards of sand, or 1-1/2 cubic yards of stone.

A fair rate of travel for a team hauling material over an ordinary dirt road is 220 feet per minute or 2-1/2 miles per hour, while an allowance of 5 minutes for loading and 5 minutes for dumping is about right. For loading and unloading cement, however, an allowance of 10 minutes for each operation must be made when the load consists of 10 barrels and 2 men are assigned to this task. A daily travel of 20 to 24 miles is a good day's work for a team.

On the average haul of 2 miles on this road a team hauling sand or stone will make a round trip in 106 minutes, or 6 round trips per 10 hour day. A team hauling cement will average 5 round trips per 10 hour day. To haul 3,016 loads of cement at an average of 5 per day, will require 603 team days, while to haul 14,938 loads of sand and stone at an average of 6 per day will require 2,489 team days. The total number of team days required will be approximately the same whether a few teams are employed for a comparatively long period of time, or a larger number of teams for a shorter period of time. There is, however, more chance for delay due to bad weather, etc., when work is spread out over a long period of time than when it is completed as soon as possible. In the average case, the hauling must be accomplished in about the same period of time devoted to laying the concrete.

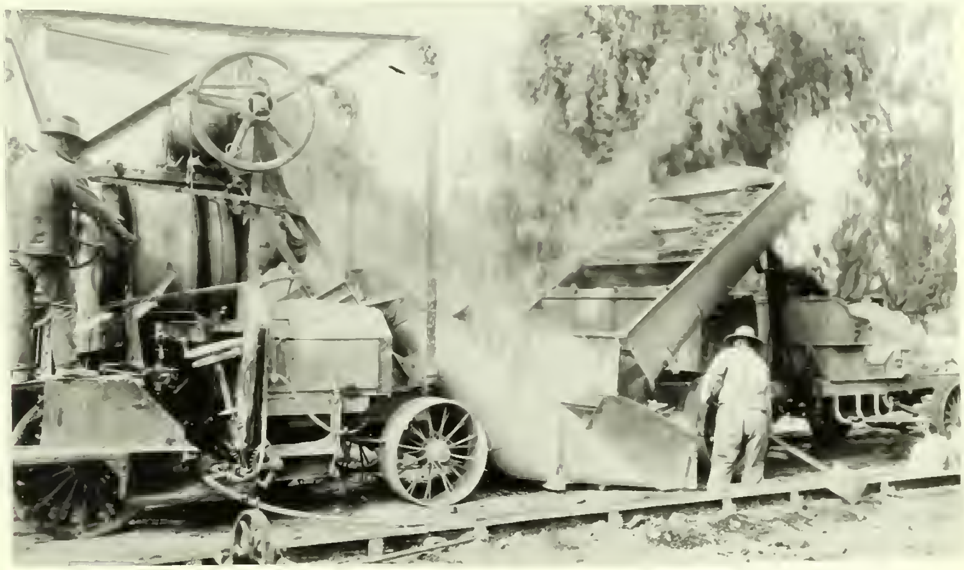
In a preceding chapter it was pointed out that 1-1/4 miles of 18 foot concrete road per month was a good rate of operation for a 14-E paving mixer, with a good organization and an ample supply of materials. At this rate about 6-1/2 months will be required for actually placing the concrete on this job, without making any allowance for delay due to waiting on grading operations, cleaning up, etc. At a rate of 20 working days per month, 130 working days will be obtained in 6-1/2 months.

Inasmuch as a total of 3,092 team days of work are necessary to haul material to this job, 24 teams must be assigned to this operation in order to complete it in 130 working days.

If 5 ton motor trucks are used for hauling material and dumping it directly on the subgrade, a total of 1,134 loads of cement, 2,688 loads of sand, and 3,630 loads of stone must be hauled. Over ordinary dirt roads an average speed of 6 miles per hour loaded and 10 miles per hour empty can be maintained with a truck of this size. An allowance of 5 minutes for loading and 10 minutes for unloading and getting away, has been shown by experience to be about right when hauling sand and stone. For hauling cement the same rate of speed can be maintained, but an allowance of 20 minutes for loading and 20 minutes for unloading must be made. On the average haul of 2 miles, a truck hauling sand or stone should make a round trip in 47 minutes or 13 round trips per 10 hour day. A truck hauling cement should make a round trip in 70 minutes, or 8 per 10 hour day. To haul 1,134 loads of cement at the rate of 8 per day will require 142 truck days, while to haul 6,318 loads of sand and stone at the rate of 13 per day will require 486 truck days. To accomplish the 628 truck days of work in 130 days, will require the services of 5 - 5 ton trucks.

Five ton trucks with dump bodies subdivided into compartments to permit 4 batches to be carried, are quite often used to dump directly into the mixer skip. At a speed of 6 miles per hour loaded and 10 miles per hour empty, with an

allowance of 5 minutes for loading and 12 minutes for dumping, a truck will perform a round trip on the average haul of 2 miles in 49 minutes. This is at the rate of 12 round trips per 10 hour day, enabling a truck to deliver 48 batches to the mixer. Six trucks are, therefore, needed to deliver 300 batches to the mixer. The photograph below illustrates the method of charging a mixer direct by means of a 5 ton truck with a subdivided body.



DIRECT CHARGING OF MIXER WITH 5 TON TRUCK

When Ford trucks are used to charge the mixer direct, an average speed of 12 miles per hour both loaded and empty is about right, with an allowance of 3 minutes for loading and 2 minutes for unloading at the mixer. At this rate a truck will make a round trip on the average haul of 2 miles, in 25 minutes, or 24 round trips per 10 hour day delivering 24 batches and traveling 96 miles. Inasmuch as the mixer requires 300 batches, at least 13 trucks must be kept in operation. To insure continuous operation, experience indicates that a surplus of one-fourth to one-third trucks must be provided on account of the severe service to which these light units are subjected.

FORD TRUCKS WITH SPECIAL DUMP BODY

In operating a combined light railway and motor truck plant, the mixer is started at the point nearest the material yard and is supplied entirely by railway until the end of the 1-1/2 miles of track is reached. At a rate of 1-1/4 miles per month, the mixer will require 1.2 months or 36 days to reach the end of the track. State specifications permit hauling over the concrete after the expiration of 21 days, and inasmuch as the mixer is assumed to operate only 20 days per month, or two-thirds of the time, about three-fourths mile of concrete will be 21 days old by the time the mixer reaches the end of the track. This, then, is the minimum truck haul. The maximum truck haul will be 2-1/2 miles in this case, while the average truck haul will be 1-5/8 miles.

Inasmuch as the trucks operate at all times over a finished road, they should average a speed of 10 miles per hour both loaded and empty. Experience indicates that an allowance of 5 minutes for loading 4 batch boxes and 10 minutes for transferring, is ample. At this rate a truck will make a round trip on the average haul of 1-5/8 miles in 34 minutes, or 18 per 10 hour day delivering 72 batches. An average of from 4 to 5 trucks will, therefore, be required on this job, when operating a combined light railway and motor truck system . In a combined light railway and motor truck system, the trucks are generally rented. On this particular job they will not be needed during the construction of the first 1-1/2 miles of road on each side of the material yard, inasmuch as the railway will serve the mixer on this portion of the work. Trucks will be required during the construction of only about two-thirds of this road. In reality, therefore, the average number of trucks required thruout the life of this job, is only 3.

DERRICK ON WAGON FOR TRANSFERRING BATCH BOXES

On the railway portion of the combined light railway and motor truck haul, the average haul from the transfer point to the mixer will be 1 mile. As previously shown, 1 - 6 ton locomotive is generally sufficient. The railway operating personnel, therefore, will consist of 1 locomotive operator and 1 train man.

A speed of 6 miles per hour and an allowance of 5 minutes for switching trains at the mixer and 5 minutes at the material yard, is a proper basis on which to proportion the amount of rolling stock required for a complete railway plant. Assuming grades do not exceed 7 per cent, we can use a 6-car, 12-batch train, splitting it on all grades over 4 per cent. On the average haul of 2 miles, the round trip can be accomplished in 50 minutes or 12 per 10 hour day. Inasmuch as

each train carries 12 batches, 1 locomotive will deliver 144 batches to the mixer per day. Two locomotives, by speeding up a trifle or occasionally using a little sand so as to permit hauling a 7 car train, can easily deliver 300 batches to the mixer. In proportioning light railway equipment it is customary, as pointed out before, to base the rolling stock upon a length of haul equal to three-fourths of the maximum. In this comparison, however, the haulage equipment will be based upon the average haul, inasmuch as this is the haul assumed for the other methods.

In charging a mixer with a 4 bag batch of materials for 1-2-3 concrete by means of wheelbarrows and shovelers, the following organization is generally required as a minimum:

3 - men wheeling sand
2 - men shoveling sand
4 - men wheeling stone
4 - men shoveling stone
3 - men handling cement
1 - man handling empty bags
17 - men

In charging a mixer direct by means of trucks or by means of light railway haulage, 2 and 3 men respectively are required at the charging end of the mixer. The Ford truck method, however, requires 2 additional men at the turntable.

When material is dumped on the subgrade or when hauling is performed over it, the subgrade must be trimmed by hand. In order to trim a sufficient amount of subgrade by hand to enable 400 feet of road to be laid per day, a subgrade gang of 10 to 12 men and a sub-foreman is required. The unobstructed subgrade characteristic of light railway haulage, permits machine trimming of the subgrade. The subgrader is generally pulled by means of a road roller, and sufficient subgrade for a day's run can be trimmed in a few hours. In operating the subgrader, men engaged in curing the concrete or in maintaining the railway track are brought back to assist in the operation. Six men will trim all the subgrade required for a day's run in 3 or 4 hours with a subgrader. This is equivalent to an average of about 2 men for 10 hours. The subgrader is sometimes pulled with a tractor.

MACHINE TRIMMING OF THE SUBGRADE

When the mixer is charged direct by means of a 5 ton or Ford truck method, the combined light railway and motor truck method, or the complete railway method, bulk cement can readily be used. The method of unloading bulk cement and handling it at the material yard, has been outlined in the previous chapter. An average of about 2 men is generally sufficient to unload bulk cement at a rate which will permit building 400 feet of 18 foot concrete road in 10 hours. When bagged cement is used, an average of about 4 men is required.

It will be assumed that a finishing machine is used on all these methods so that the personnel required for setting forms and for finishing will be the same for all.

The personnel required for a job of the kind we have assumed, under average conditions, is about as follows:

MEN REQUIRED	SYSTEM					
	HAND CHARGING		DIRECT CHARGING			
	Team	5 Ton Truck	Ford Truck	5 Ton Truck	Comb. Rwy. and Truck	Complete Railway
Material Yard						
Crane Operator	1	1	1	1	1	1
Crane Fireman	1	1	1	1	1	1
Bucket Man	1	1	1	1	1	1
Car clean-up men	2	2	2	2	2	2
Unloading bagged cement	4	5	*	*	*	*
Unloading bulk cement	*	*	2	2	2	2
Bin Gate Men	2	1	2	1	1	*
Tunnel Men	*	*	*	*	*	2
Water Boy	1	1	1	1	1	1
Hauling Material						
Team Drivers	24	*	*	*	*	*
Stable Men	4	*	*	*	*	*
Truck Drivers	*	5	13	6	3	*
Garage Men	*	2	2	2	*	*
Locomotive Operators	*	*	*	*	1	2
Train Men	*	*	*	*	1	2
Man to fill radiators	*	*	1	*	*	*
Turntable Men	*	*	2	*	*	*
Transfer Point Men	*	*	*	*	3	*
Track Men	*	*	*	*	2	3
Material Yard and Hauling Foremen	1	1	1	1	1	1
Mixing and Placing Concrete						
Mixer Operator	1	1	1	1	1	1
Mixer Fireman	1	1	1	1	1	1
Finishing Mach. Operator	1	1	1	1	1	1
Concrete Spreaders	3	3	3	3	3	3
Charging mixer	17	17	2	2	3	3
Setting Forms	3	3	3	3	3	3

	HAND CHARGING		DIRECT CHARGING			
	Team	5 Ton Truck	Ford Truck	5 Ton Truck	Comb. Rwy. and Truck	Complete Railway
Mixing and Placing Concrete						
Trimming Subgrade	12	12	12	12	2	2
Sub-foreman on subgrade	1	1	1	1	*	*
Roller Operator	1	1	1	1	1	1
Curing Concrete	4	4	4	4	4	4
Pump Man	1	1	1	1	1	1
Pipe Man	1	1	1	1	1	1
Water Boy	1	1	1	1	1	1
Watchman	1	1	1	1	1	1
Foreman	1	1	1	1	1	1
	89	67	62	50	42	41

In addition to the operating personnel listed above, a superintendent is generally in charge of the entire job. A time-keeper, a material clerk, a general office man for the field office, and a cost keeper are provided on the average fair sized job. A garage for field repairs with 1 mechanic and helper, must be provided in order to keep the motor trucks in shape. Particularly is this true with the Ford trucks, for they travel an average of 96 miles per day. The average travel of the 5 ton trucks is 56 miles. No garage men are provided for the combined light railway and motor truck plant, inasmuch as the motor trucks are generally rented and the owner provides for their repair in his rental charge. A blacksmith and a helper are generally necessary on a job of this size.

Each contractor has his own arrangement for paying his men, but all of them generally have a certain number "straight-time" men. These men are paid the regular wage on rainy days as well as working days. Most contractors carry a few men thruout the year as a nucleous for their organization, generally the foremen and sub-foremen, the mechanics, the crane operator, and the mixer operator. The foremen and the superintendent are paid either by the month or by the year, while the rest of the personnel, except the "straight-time" men, are paid only for the actual time they work. Frequently the office force, or at least a part of it, are carried thruout the year. Most progressive contractors employ an engineer for the purpose of checking the quantities shown on the plans, and for doing such other engineering work as is necessary.

CHAPTER XII.

COST OF OPERATION.

One of the most common mistakes in highway construction, in judging the merits of a plan of operation, is to give undue consideration to the cost of hauling, regardless of the fact that hauling is but one of a number of coordinated functions which must be performed, though it is no doubt one of the most important. If hauling were the only operation to be performed in road building, then the cost per ton mile would be the proper criterion upon which to base judgment. In order to correctly judge of the merits of any system of road building, all of the operations involved must be considered as a whole. It is manifestly false economy to adopt a plan of operation because the cost of hauling is lower than by some other plan, but where the losses due to extra labor involved in charging the mixer and trimming the subgrade, loss of material due to dumping on the subgrade, loss due to extra concrete because of inaccurate subgrade, etc., will more than absorb any saving in the cost of hauling. The actual cost of hauling per ton mile by the combined light railway and motor truck system on a small job, 3 or 4 miles long, is frequently greater than it would be if teams or trucks were hired by the day. The economy effected in charging the mixer, trimming the subgrade, reduction of delay due to wet weather, etc., by the combined light railway and motor truck system, however, will more than compensate for the increased cost of hauling. In spite of all this, however, undue emphasis is frequently placed on the cost of hauling per ton mile.

Another common and costly mistake frequently made, is to assume a uniform cost per ton mile for hauling regardless of the length of haul. The cost of hauling per ton mile varies inversely with the length of haul. When a comparatively expensive plant, such as light railway or motor truck, is used on a short haul, the actual cost of hauling per ton mile is frequently greater than by team. As the haul increases, however, the railway and truck cost finally becomes less than that by team. A cost per ton mile for hauling is absolutely no good, unless the length of haul and percentage of waiting time involved is also given.

The cost of hauling, like any other cost, varies with local conditions, with the length of working season and weather conditions, and with the managing ability of the contractor. It is obvious that the unit cost of hauling in hilly country or on roads of a certain character, will differ considerably from the cost in level country or on roads of another character. In a part of the country where the working season is longer than it is in another part, the unit cost of hauling will be less. Plant and overhead charges must be provided for during the working season, no matter how short it may be. A greater amount of work can be performed in a long season than in a short one, and in a long season fixed charges can be spread over greater mileage than in a short season. The unit cost of hauling in a wet climate, is generally greater than in a dry climate. On certain jobs it might be necessary, for business reasons, to charge off a greater percentage for depreciation than on other jobs, and in such a case the unit cost of hauling will be increased. Equipment purchased during a period of unusually high prices, should be charged off at a greater rate than equipment purchased during a normal or a rising market. All of these factors influence unit costs very materially, and on this account a contractor should use great caution with figures from some other job or part of the country where conditions are not fully known to him. Data issued by manufacturers of equipment frequently omits many vital factors which go to make up a cost, and this data should be used by contractors only after

careful scrutiny.

In the final analysis cost is merely a relative term, and is not by any means absolute or fixed. The cost to one man of performing a certain work, might be entirely different from the cost to some one else, on account of certain peculiarities of temperament or conditions. It is again desired to emphasize, therefore, that any cost obtained under conditions not absolutely known, should be used only as a guide and with caution.

The term cost is a composite one, including a large number of elements. All too frequently the inexperienced man fails to place proper emphasis on some of the more or less intangible elements, because his vision is obscured by the concrete elements of labor and materials. While it is true that the cost of labor and materials generally forms the greater part of the final cost, it is equally true that failure properly to consider other elements will result in a loss even though the cost of labor and material has been properly estimated. Or if the other elements which make up a cost in addition to labor and material have been kept in mind, the mistake is frequently made of providing for them insufficiently.

Perhaps the element of plant charges is more frequently under-estimated than any of the other so-called intangible elements. The danger of this practice is due to the fact that it is generally not discovered for a number of years, with the result that the apparent profit earned during the previous years is very considerably reduced or is really not a profit at all. Failure properly to estimate other elements of a cost generally becomes apparent at least by the completion of the job, but failure to make proper plant charges is not apparent at once and is, therefore, much more dangerous.

Plant charges consist of depreciation on the equipment, interest on the investment, field repairs, shop repairs, storage charges, insurance, and obsolescence. These charges are generally expressed in terms of a percentage of the initial cost of the equipment. The proper percentage to be charged depends upon the type of equipment and whether it is special or standard, upon the job and the conditions under which it is employed, and upon its second hand value and scrap value. A piece of special equipment purchased for a particular job, which will probably be of but little further use, should obviously be charged entirely to this one job. The type of equipment will affect the plant charge very materially, for it is apparent that a steam shovel or a heavy earth moving car will last longer than a concrete mixer or a finishing machine. If equipment is operated on a double shift, the rate of depreciation and the amount of repairs will naturally be greater than if it is operated on a single shift. A steam shovel or cars working in rock, will naturally wear out faster than if working in earth. Some equipment will have a considerable scrap value, while other equipment will have practically none. Some equipment will have a higher second hand value and a broader second hand market, than other equipment. Some equipment might have been purchased during a period of high prices, while other equipment might have been purchased during a period of normal or low prices. All of these factors must be considered and proper weight given to them, in deciding upon plant charges.

The estimated rate of depreciation is not always based upon the probable life of the equipment, but frequently upon the time in which the business judgment of the contractor indicates that he must recover his investment. For instance, most concrete mixers will last for 6 or 7 years, but it is common practice to base the rate of depreciation in computing plant charges upon a life of 4 years.

More mistakes are made in estimating plant charges than in any other element of cost, and a considerable amount of experience is required for an intelligent estimate. A copy of a "Guide for Estimating Construction Plant Charges" recently issued by the Associated General Contractors of America, will be found in the appendix. This Guide represents the consensus of opinion of a considerable number of contractors as to what proper plant charges should be.

One thing which must always be kept in mind, is that plant charges must be earned during the construction season, no matter how short it may be. For instance, a contractor might purchase motor trucks to be used in road building during, say, 6 months of the year. He might charge only half of the yearly plant charges to the road work, assuming that the other half will be earned during the winter time in performing other work such as hauling coal. Unless he has absolute assurance that he will be able to obtain work for his trucks outside of his road work, such a procedure is very risky. Even though he has proper assurance that he can haul coal during the winter time, it is not good business for him to depend upon an auxiliary operation to carry part of the plant charges on equipment purchased primarily for road work. If equipment is purchased primarily for accomplishing some purpose, all of the plant charges should be charged to it. If this can not be done without making the cost excessive, then obviously the equipment is not the proper kind for the purpose in mind.

A contractor is frequently confronted with the problem of deciding just what proportion of the yearly plant charges is to be assigned to some one job. This job might be secured early in the year, and might not be of quite sufficient size to keep him busy during the entire season. He must then decide whether to assign all the plant charges for the year to this one job, or whether to assign only a portion in the expectation of securing another contract which will absorb the remainder. The decision in this matter must be based upon local conditions, and upon the experience and judgment of the individual. If all the yearly plant charges are assigned to the first job, the cost might be so high as to preclude securing the contract, while if only a part is charged to the first job, the risk is incurred of not securing another job to carry the remainder.

In addition to the plant charges, there are a number of other important charges which go to make up a cost. Some of these charges are directly applicable to each job, while others are general charges which must be pro-rated among the various jobs. The cost of erecting bins and tunnels and dismantling them, loading and unloading equipment, freight on equipment to and from the job, the cost of erecting and operating the field office, certain traveling expenses, etc., are generally directly chargeable to each job. If bins and tunnels are so constructed that they can be dismantled and moved from one job to another, it would be proper to assign a certain proportion for depreciation, etc., to each job. When equipment is shipped to a job, it is seldom known whether it will be reshipped from that job to another one or back to the contractor's yard. It is generally wise, therefore, to charge freight both ways from the contractor's yard to the job.

When a camp is operated by the contract system, the cost to the contractor is generally fixed. A well operated, sanitary camp, is the best precaution a contractor can take to insure an adequate supply of efficient and contented labor. Rather than run the risk of a poor camp by contracting for its operation, it is generally better for a contractor to operate the camp himself. Even though a sufficient charge cannot be made for board and room to make the camp self-sustaining, it is always a good investment to maintain a good camp and charge the loss to "overhead".

The term "overhead" represents the least tangible of the many elements which comprise a cost. "Overhead" can really be divided into two general classes, namely, "job overhead" and "general overhead". "Job overhead" includes superintendents, field office expense, traveling expense, watchmen, timekeepers, cost keeper, clerks, telephones, stationery, lights, and all other costs on a job not directly assignable to some other element. "General Overhead" includes the executive and administrative expenses of operating the general office, cost of securing work, attending conventions, salaries of employees during winter months, feed of stock during winter months, and all the expenses not directly attributable to some particular job. "General overhead" is pro-rated among the various jobs in accordance with the experience and judgment of the contractor, and naturally varies with particular conditions and organization. The larger the organization the larger the "overhead" as this is one of the penalties of size.

Each contractor generally has his own cost system, which he considers to be more or less adapted to his own peculiar conditions and problems. This of course is frequently so, and no attempt will be made in this thesis to enter into a detailed discussion of various cost keeping systems. The Wisconsin Highway Department has recently prepared a schedule for highway contractors containing the many elements of cost involved in road building, a copy of which will be found in the appendix. Bulletin #660, of the United States Department of Agriculture, entitled "Highway Cost Keeping", treats of cost keeping forms and methods. This bulletin can be secured from the Superintendent of Documents of the Government Printing Office, in Washington, D. C.

While it is not desired to enter into a detailed discussion of methods of cost keeping, still it is believed to be desirable to point out some of the essential features which a good system should include. The cost of fuel and oil should be kept separate, as well as the cost of common labor and the cost of skilled labor. The cost of foremanship should be kept separate from the cost of labor, because the proportionate cost due to foremanship varies with each job. The "job overhead" should be kept separate from the "general overhead" and the cost of securing business, such as looking over work, making out bids, advertising, etc., should be kept by itself. The cost of superintendents, time keepers, clerks, watchmen, books and stationery, field office expense, etc., should all be kept separate. Above all, full and complete data concerning the conditions surrounding a job should be recorded. Photographs will help materially in bringing to mind conditions years after the work has been completed, and should be liberally used. Cost data ~~is~~ are all too often rendered valueless by failure properly and sufficiently to describe the prevailing conditions when it was obtained, and much of it is not properly subdivided or analyzed so as to permit it to be applied to other work of like or similar character. Too much emphasis cannot be placed upon the absolute necessity of providing full and complete data to accompany information on cost, if this information is to be of much value after the figures are "cold".

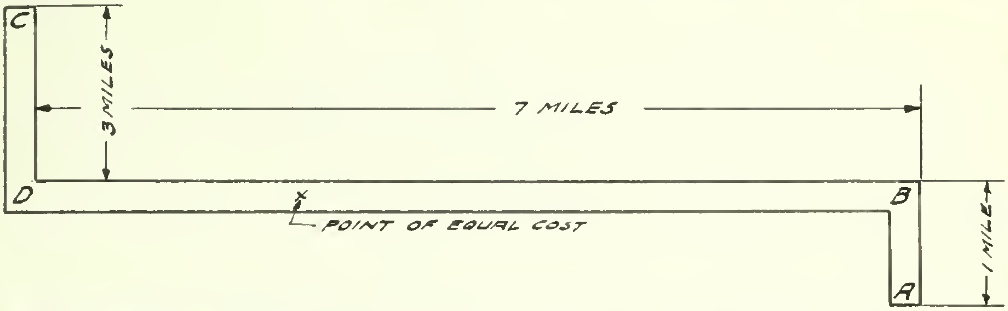
A common practice in estimating cost is to estimate first the unit cost, and then to obtain the total cost by multiplying the unit cost by the number of units. In certain work, such as earth work, this is the method that must generally be used, but in hauling, mixing concrete, or unloading material, a better method is to estimate the total cost and then obtain the unit cost from the total if desired. For instance, in estimating the cost of placing concrete, contractors frequently figure the daily cost per square yard. Certain additions must then be made to provide for delays due to rain, loss due to inaccurate subgrade, etc., and inasmuch as the units involved are small, an error of a few cents will represent a considerable percentage of the cost. A better method is to estimate the total time and total cost required to complete the work, making such allowance for delay due

to wet weather, starting and stopping the job, moving the material yard, lack of material, etc. as experience and judgment dictates. Proper allowance can readily be made for loss of material, straight time men, etc. If the method of estimating by totals is followed, there is less chance of improperly providing for contingencies than in the method of estimating by units.

Sometimes several unloading points are available, and the question arises as to how much of the road lying between two of them is to be constructed with material hauled from each. The problem is further complicated by the fact that the cost of establishing one material yard is frequently greater than the cost of establishing another, and the cost of material at one point is greater than it is at another. The general rule of dividing the road so as to equalize the maximum haul from each material yard, must, therefore, be changed to dividing the road so that the unit cost of material from either yard at the dividing point is the same. This rule must sometimes be modified considerably in order to adapt the equipment on hand to the job, to eliminate grades opposed to the loaded train, etc. It is generally worth while, however, to determine the points of equal cost on a road and to adhere to them as closely as is practical, for material is frequently hauled from one yard when it could be more economically hauled from another.

The problem of determining the point of equal cost is not involved in that of determining the number of unloading points to use, for a decision in this respect should have already been reached. In determining the point of equal cost, it is obvious that the increased cost of establishing one material yard over that of establishing another must be absorbed by the tonnage of material hauled from that yard.

In order to illustrate the method of dividing a road when material is hauled from two unloading points, we will consider a road such as that shown in the sketch below.



Material was available on railroad sidings at points "A" and "C", and the cost of hauling from either unloading point to the road "BD" was estimated at $0.40 per ton mile. A mixer was started at point "B" and the problem was to determine how much road to build with material hauled from "A" and how much with material hauled from "C". A siding was already in place at "C", but an expenditure of $3,000 was necessary to provide a siding at "A". The combined light railway and motor truck system of haulage was used. The material required was as follows:

Cement	3,760 bbls. or	718	tons per mile;	5,026	tons per 7 miles
Sand	1,120 cu.yds.or	1,680	tons per mile;	11,760	tons per 7 miles
Stone	1,680 cu.yds.or	2,270	tons per mile;	15,890	tons per 7 miles
		4,668 tons		32,676 tons	

The cost of material was approximately as follows, the cement price per ton being derived from a price of $2.50 per barrel and a weight of 376 pounds.

	POINT "A"	POINT "C"
Cement per ton	\$13.30	\$13.30
Sand per ton	0.60	1.25
Stone per ton	2.00	2.00

The proportions of 1-2-3 by volume are equivalent to 1.00-2.36-3.19 by weight, based upon a weight of 276 pounds per barrel of cement, 3,000 pounds per cubic yard of sand, and 2,700 pounds per cubic yard of stone. The weighted mean cost of material at each point is, therefore, as follows:

POINT "A"

1.00	x \$13.30	=	\$13.30
2.36	x 0.60	=	1.42
3.19	x 2.00	=	6.38
6.55			\$21.10

$\frac{\$21.10}{6.55}$ = \$3.22, the weighted mean cost per ton at "A"

POINT "C"

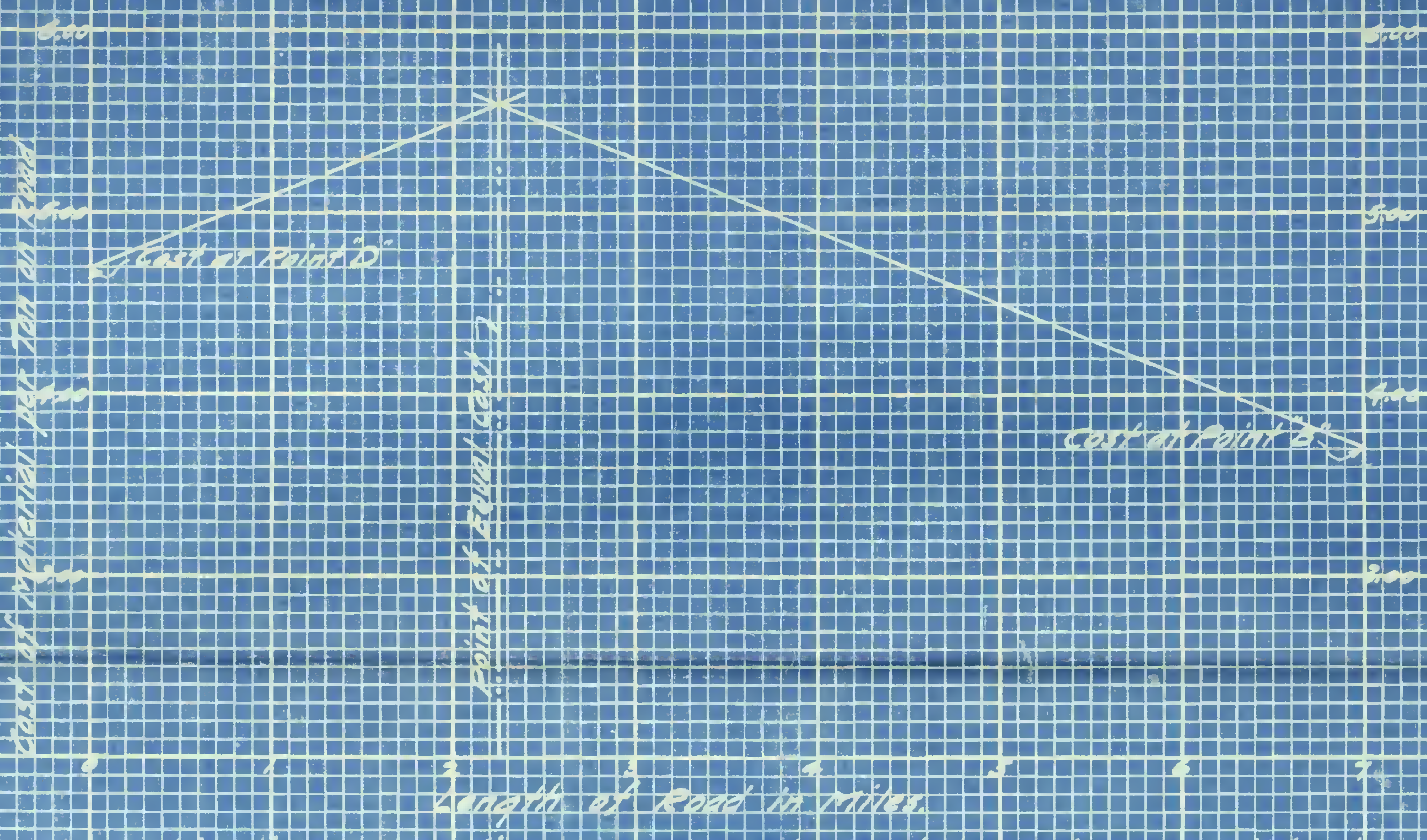
1.00	x \$13.30	=	\$13.30
2.36	x 1.25	=	2.95
3.19	x 2.00	=	6.38
6.55			\$22.65

$\frac{\$22.65}{6.55}$ = \$3.45, the weighted mean cost per ton at "C"

Let X represent the mileage of road to be constructed with material hauled from "A", and Y the mileage to be constructed from "C". The tonnage of material hauled from "A", therefore, equals 4,668 X. The weighted mean cost of material per ton at "A" is \$3.22, while the cost at "B", after hauling 1 mile, is \$3.62. The weighted mean cost of material at "C" is \$3.45, while the weighted mean cost at "D", after hauling 3 miles, is \$4.65. The cost of material hauled from "A" at any point along the road distant X from "B", will be \$3.62 plus $\frac{\$3,000}{4,668\ X}$ plus \$0.40 X equals \$3.62 plus $\frac{\$0.64}{X}$ plus \$0.40 X. The cost of material hauled from "C", at any point Y from "D", is \$4.65 plus \$0.40 X. Equating these expressions gives a value of 4.62 miles for X. In other words, under the conditions assumed, material hauled 4.62 miles from point "B", is equal in cost to material hauled 2.38 miles from point "D". This, therefore, indicates the mileage of road to be built with material from each unloading point, in the absence of other modifying conditions. If a complete railway system were employed, a division of the road such as that indicated above would involve more equipment than if the maximum haul from each point was equalized. In such a case it might be more economical to divide the road so as to reduce the amount of equipment required, rather than to divide it strictly in accordance with the point of equal cost.

The accompanying graph illustrates a graphical method of determining the point of equal cost. The advantage of the graphical method is that it readily indicates the extra cost involved, when material is hauled beyond the point of equal cost. For instance, in the example shown above, suppose that it is desired to determine the increased cost due to building $3\frac{1}{2}$ miles of road from "C" rather than the 2.38 miles indicated by the curve. By continuing the curve representing the cost of material hauled from point "C" to the 3-1/2 mile point, we see that the unit cost would be \$6.10 per ton rather than the \$5.20 when hauled from "A". The area of the triangle shown by the cross-hatching gives the total increase in cost, when the altitude is taken in terms of tons of material. In this particular case the increased cost would be \$6.10 minus \$5.20 times (4,668 x 1.12) times 1/2 equals \$2,362.00. A study of this character will enable the contractor to ascertain whether the increased cost is justified by the plan he has in mind.

DIAGRAM
SHOWING
ECONOMIC LIMIT OF HAUL
FROM
EACH OF SEVERAL UNLOADING POINTS
IN HIGHWAY CONSTRUCTION.



This diagram applies to a case where sidings already exist at unloading points and no expenditure for siding installation is necessary.

DIAGRAM No. 1

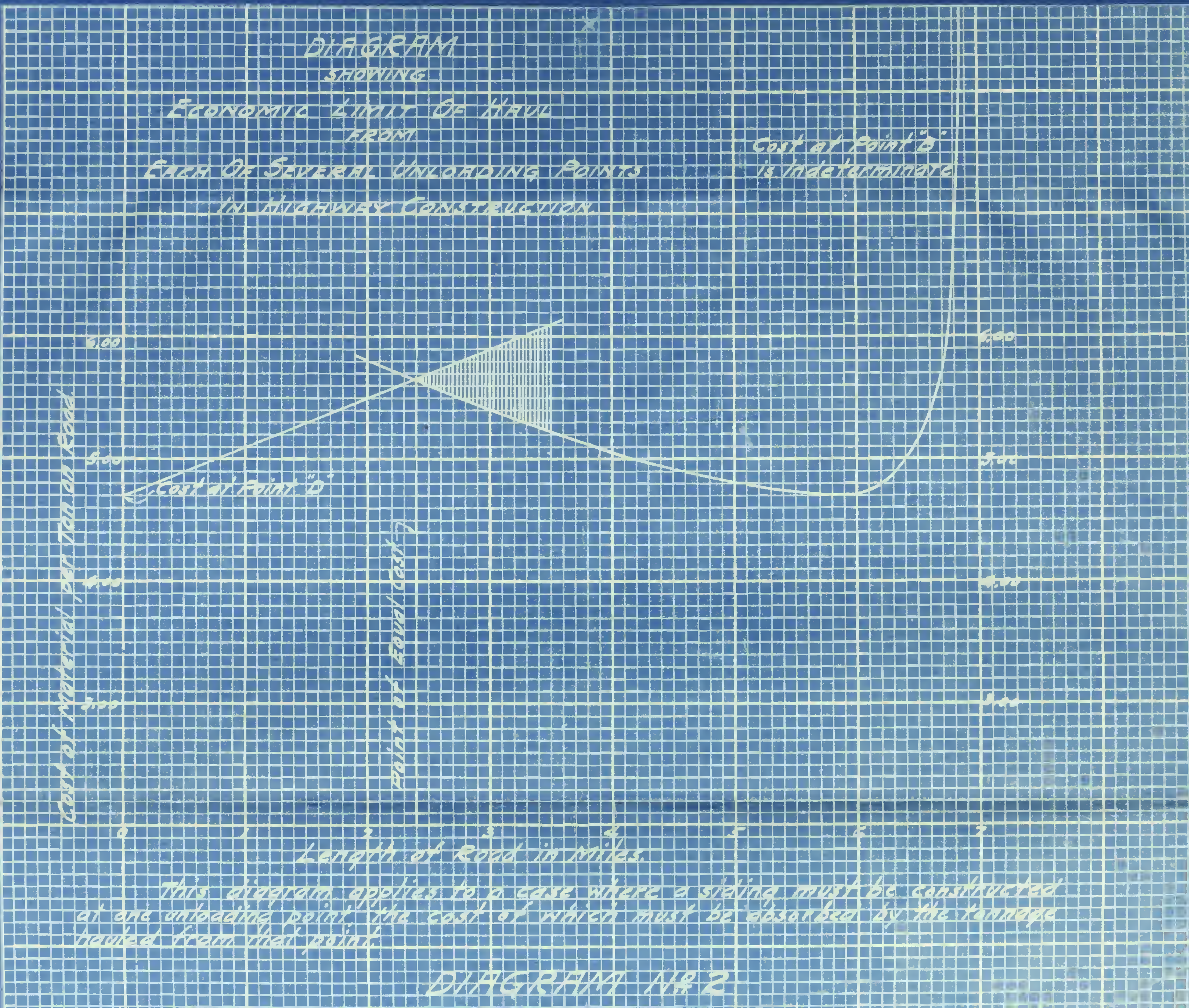


DIAGRAM
SHOWING
ECONOMIC LIMIT OF HAUL
FROM
EACH OF SEVERAL UNLOADING POINTS
IN HIGHWAY CONSTRUCTION.
Cost at Point "B"
is indeterminate
Cost at Point "D"
Point of Equal Cost
Cost of material per ton on Road
0
1
2
3
4
5
6
7
Length of Road in Miles.
This diagram applies to a case where a siding must be constructed
at one unloading point, the cost of which must be absorbed by the tonnage
hauled from that point.
DIAGRAM No 2

In order to illustrate the method of estimating and the relative economy of various systems of road building, a typical estimate of the cost of operation will be shown. No attempt will be made to consider overhead charges, cost of material, workmen's compensation and accident insurance, public liability insurance, contractors bond, etc. A road 8 miles long with the unloading point opposite the center and 1 mile away, will be considered. The type of pavement will be concrete, 18 feet wide, 7-1/3 inches in average thickness, and of a 1-2-3 mixture. The output of road will be assumed to be 1-1/4 miles per month, under normal conditions, with a 14-E mixer. At this rate the concrete should be placed in about 6-1/2 months or 130 working days.

A traction crane costing $10,000, equipped with a 35 foot boom and a 3/4 yard clam shell bucket, will be used for unloading material, The tunnel system of storage will be used for the light railway plant, and a 200 cubic yard bin and stock piles for the motor truck, and combined light railway and motor truck, plants. Detailed drawings of the tunnel and bin will be found in the appendix.

A 14-E paving mixer operating at a rate of 400 feet of road per 10 hour day, will require the following quantity of material:

285 bbls. cement	or 54 tons	or 1-1/2 cars.
85 cu.yds. sand	or 127 tons	or 2-1/2 cars
127 cu.yds.stone	or 172 tons	or 3-1/2 cars
		7-1/2 cars.

A crane of the type we have assumed is capable of unloading from 10 to 12 cars of material per 10 hour day, so it has ample capacity for the purpose we have in mind. The cement will be shipped in bulk in open top cars, and will be unloaded into a bin in the same manner as sand and stone.

The plant charges, consisting of interest, depreciation, repair, etc. are in accordance with the "Guide to Estimating Construction Equipment Expense" recommended by The Committee on Methods of the Associated General Contractors. No plant charges or fuel charges are made for rented equipment, as these charges are taken care of by the owner of the equipment in his rental.

COST OF UNLOADING AND PROPORTIONING MATERIAL

1 crane operator 7 months	@ $180.00	$1,260.00
1 crane fireman 7 months	@ $144.00	1,008.00
1 bucket man 140 days	@ 4.00	560.00
2 clean up men 130 days	@ 4.00	1,040.00
2 bin or tunnel men 130 days	4.00	1,040.00
1 water boy 130 days	@ 2.00	260.00
coal and oil 140 days	@ 8.00	1,120.00
	Labor and Fual	$6,288.00
Plant charge on crane @ 34½%		3,450.00
Plant charge on 31 tunnel traps @ 37%		270.00
Plant charge on clam shell bucket @ 50%		350.00
Plant charge on 250 feet of tunnel @ 67%		1,675.00
Plant charge on 1500 bbl. bulk cement bin @ 67%		1,675.00
	Plant charges	$7,420.00

Dismantle tunnel, 25,200 feet of lumber, @ \$5.00	\$ 126.00
Dismantle bin, 16,000 feet of lumber, @ \$5.00	80.00
Load 41,200 feet lumber, board measure, @ \$2.00	82.00
Freight on lumber, 24¢ cwt.(ship 150 mi.)	331.00
Freight on crane, 24¢ cwt., 40,000#	96.00
Load and unload crane @ \$2.00 per ton	40.00
Rental of ground, about 1 acre	200.00
Back fill tunnel trench and clean up	300.00
Railroad charge, installing switch points and frog	1,200.00
700' siding after rebate for rails and ties	1,400.00
	\$3,855.00

Total cost of unloading and proportioning material \$17,563.00

Cost per ton, unloading and proportioning material \$ 0.47

If a 200 cubic yard bin is used in place of a tunnel, it would cost about \$1,500.00. Considering the greater amount of rehandling of material necessitated by a bin, the final cost of unloading and proportioning material would be just about the same as for the tunnel system shown above.

If the 5 ton motor truck method of hauling material is used and material is dumped on the subgrade, a speed of 6 miles per hour loaded and 10 miles per hour empty is a good average over fairly good earth road. At this rate, allowing 5 minutes for loading and 10 minutes for dumping and getting away, a truck should make the round trip of 6 miles on the average haul in 63 minutes. This is equivalent to 9 round trips per 10 hour day. The sand and stone required on this job amounts to 6,318 - 5 ton loads, and inasmuch as 1 truck should average 9 trips per day,702 truck days are required for hauling sand and stone. To perform this amount of work in 130 days, 6 trucks must be assigned to the task. To haul 30,166 barrels of cement will require 1,134 - 5 ton loads. At a speed of 6 and 10 miles per hour for loaded and empty trucks respectively,with an allowance of 20 minutes for loading and 20 minutes for unloading and piling a 26 barrel load of cement, the round trip on the average haul of 3 miles should be performed in 88 minutes. This is at the rate of 7 per 10 hour day, requiring 162 truck days of work to haul 1,134 loads of cement. The services of 1-1/4 trucks are necessary to perform this amount of work in 130 days, and inasmuch as cement cannot be stored on the road in any considerable quantity,it is necessary to assign 2 trucks to haul cement. A total of 8 trucks are, therefore, necessary with this system.

When a 5 ton truck with a subdivided dump body is used to charge the mixer direct, the speeds of 6 and 10 miles per hour for loaded and empty trucks, respectively,will apply. At this rate, with an allowance of 12 minutes for dumping 4 batches into the skip of the mixer and getting away, a truck will make a round trip on the average haul of 3 miles in 65 minutes. This is at the rate of 9 trips per 10 hour day, enabling each truck to deliver 36 batches to the mixer. To deliver 300 batches per day will require the services of 9 trucks.

A Ford truck,carrying complete materials for 1 - 4 bag batch of concrete, will average a speed of about 12 miles per hour loaded and empty. At this rate, allowing 3 minutes for loading, filling radiator, etc. and 2 minutes for dumping into the mixer, 35 minutes are required per round trip on the average haul of 3 miles. This is at the rate of 17 trips per 10 hour day, so that 18 trucks are needed to deliver 300 batches to the mixer. Experience indicates that a surplus of about one-third of the number of trucks required to supply the mixer must be

provided in a light truck plant, because of the severe operating conditions. A set of oversized tires should not be counted on to give much more than 4,000 miles of service, nor a gallon of gasolene much more than about 8 miles of travel.

In the combined light railway and motor truck plant, the truck haul varies from a minimum of 1 mile to a maximum of 3-1/2 miles. Over the 1 mile of unimproved road between the material yard and the job, a speed of 6 miles per hour loaded and 10 miles per hour empty is a fair average for 5 ton trucks. A speed of 10 miles per hour both loaded and empty should be maintained over the finished pavement. Allowing 5 minutes for loading and 10 minutes for transferring 4 batch boxes, a truck will require 31 minutes per round trip on the minimum haul of 1 mile. This is at the rate of 19 trips per 10 hour day, enabling each truck to deliver 76 batches. Four trucks will easily deliver 300 batches to the light railway on the 1 mile haul. On the maximum haul of 3-1/2 miles, a round trip will require 61 minutes. This is at the rate of 10 trips per 10 hour day, enabling each truck to deliver 40 batches. The services of 8 trucks are required to deliver 300 batches to the transfer point on the maximum haul. An average of 6 trucks will be needed thruout the job.

At a speed of 6 miles per hour, allowing 5 minutes for switching at the mixer and 5 minutes at the material yard, a locomotive will make a round trip on a 3.75 mile haul, three-fourths of the maximum, in 85 minutes. With a 7 car train carrying 14 batches, 3 locomotives and 5 trains are needed to supply 300 batches to the mixer.

The haulage equipment required for each plan of operation, assuming trucks are rented for the combined light railway and motor truck plant, is as follows:

	COMPLETE RAILWAY		COMBINED SYSTEM		5 TON TRUCK HAND CHARGE	5 TON TRUCK DIRECT CHARGE	FORD TRUCK
Track,	5.25 mi.	$33,171	1.5 mi.	$9,478	......	......	......
1/2 turnout,	14	2,100	4	600	......	......	......
Curved sec.	25,	349	10	139	......	......	......
Locomotives,	3	13,800	1	4,600	......	......	......
Cars,	35	4,375	24	3,000	......	......	......
Batch boxes,	70	4,984	88	6,266	......	......	......
Flat Cars,	2	830	1	415	......	......	......
Trans. derrick		.....	1	1,500	......	......	......
Motor trucks		.....	6	(rented)	8- $48,000	9- $54,000	24-$24,000
		$59,609		$25,998	$48,000	$54,000	$25.000

The cost of hauling on this job should be about as follows:

	COMPLETE RAILWAY	COMBINED SYSTEM	5 TON TRUCK HAND CHARGE	5 TON TRUCK DIRECT CHARGE	FORD TRUCK
Loco.operators, 7 mo. @ $120.00	$2,520	$ 840	......	......	......
Train men, 130 da. @ $4.00	1,560	520	....	......	......
Gas & oil for loco. 140 da. @ $5.00	2,100	700	......	......	......
Gas & oil for trucks 140 da. @ $5.00	.....	......	$5,600	$6,300	$12,600

	COMPLETE RAILWAY	COMBINED SYSTEM	5 TON TRUCK HAND CHARGE	5 TON TRUCK DIRECT CHARGE	FORD TRUCK
Truck drivers, 140 da. @ $5.00	......	......	$5,600	$6,300	$12,600
Trans. Derrick Men 130 da. @ $4.00	......	$1,560	......	......	......
Lay & remove track, @ $200.00 per mi.	$2,400	2,500	......	......	......
Track men, 130 da. @ $4.00	1,560	1,040	......	......	......
Turntable men, 130 da. @ $4.00	......	......	......	......	1,040
Radiator man, 130 da. @ $4.00	......	......	....	......	520
Labor and Fuel	$10,040	$7,160	$11,200	$12,600	$26,760
Rental of trucks, 140 da. @ $40.00	......	33,600	......	......	......
Plant Charge					
Track, @ 30½%	10,864	3,116	......	......	......
Locomotives, @ 52%	7,176	2,392	......	......	......
Cars, @ 34%	1,770	1,161	......	......	......
Batch Boxes, @ 34#	1,695	2,130	......	......	......
Trans. derrick @ 33%	......	500	......	......	......
5 ton trucks, @ 75%	......	......	$36,000	$40,500	......
Ford trucks, @ 81%	......	......	......	......	$19,440
	$21,505	$9,299	$36,000	$40,500	$19,440
Load & unload equip. @ $4.00 per ton	770	266	......	......	......
Freight, ship 150 mi. @ $0.44 per cwt.	3,390	1,172	......	......	......
Gas & oil, moving 150 mi.	......	......	105	118	132
Tires, move 150 mi. @ $0.07	......	......	84	95	......
Tires, move 150 mi. @ $0.03	......	......	......	......	108
Truck drivers, moving 150 mi.	......	....	130	147	240
License fee, @ $50.00	......	......	400	450	......
License fee, @ $20.00	......	......	......	......	480
Tires, 7,000 mi. @ $0.07	......	......	3,930	4,410	......
Tires, 13,260 mi. @ $0.03	......	......	......	......	7,160
Complete insurance	......	......	3,200	3,600	1,800
	$4,160	$1,438	$7,829	$8,820	$9,920

	COMPLETE RAILWAY	COMBINED SYSTEM	5 TON TRUCK HAND CHARGE	5 TON TRUCK DIRECT CHARGE	FORD TRUCK
Cost of operation, labor, fuel, & plant	$34,279	$50,470	$55,029	$61,920	$56,480
Cost per ton mile	$ 0.31	$ 0.45	$ 0.49	$ 0.55	$ 0.50

If trucks are rented for the 5 ton direct charging system at $40.00 per day, the cost would be $50,400 for 140 days. The cost per ton mile would be $0.45

In the foregoing no allowance is made for fuel and oil, drivers, or plant charges for motor trucks on the combined light railway and truck system, because the rental charge includes all of these items.

The daily cost per 5 ton truck when material is dumped on the subgrade is $48.00 per truck, based upon 140 working days. This illustrates the statement previously made that contractors can generally rent trucks for less than the cost of operating their own trucks. The comparatively short working season in highway construction, is responsible for this condition.

The cost of mixing and placing concrete, should be approximately as follows:

EQUIPMENT REQUIRED

1 14-E paving mixer	$ 7,925
1 10-ton roller	4,000
1 finishing machine	1,800
1 subgrader	600
2000' - 6" steel form @ $0.912	1,824
1 double unit pump	1,500
10,560' - 2" wrought iron pipe @ $0.32	3,379
132 tees, @$0.36 (80-ft. apart)	48
8 gate valves, @ $4.20	34
600 sq.yds. tarpaulin, @ $1.08	648
	$21,758

The concrete mixing and placing equipment shown above is for a complete railway or a combined light railway and motor truck plant. When material is dumped on the subgrade or the mixer is charged direct from motor trucks, the subgrader should be omitted. An allowance of $100.00 for wheelbarrows and shovels should be made when material is dumped on the subgrade.

LABOR AND FUEL

	COMPLETE OR COMBINED RWY.	5 TON TRUCK HAND CHARGE	5 TON TRUCK DIRECT CHARGE	FORD TRUCK
Mixer operator, 7 months, @ $180.00	$ 1,260	$ 1,260	$ 1,260	$ 1,260
Mixer fireman, 7 months, @ $144.00	1,008	1,008	1,008	1,008

	COMPLETE OR COMBINED RWY.	5 TON TRUCK HAND CHARGE	5 TON TRUCK DIRECT CHARGE	FORD TRUCK
Finishing Mach. operator, 7 months, @ $144.00	$ 1,008	$ 1,008	$ 1,008	$ 1,008
Pump Operator, 7 months, @ $144.00	1,008	1,008	1,008	1,008
Roller Operator, 7 months, @ $180.00	1,260	1,260	1,260	1,260
Head form setter, 130 da. @ $5.00	650	650	650	650
Form setter helpers, (2) 130 da. @ $4.00	1,040	1,040	1,040	1,040
Concrete spreaders, (3), 130 da. @ $4.00	1,560	1,560	1,560	1,560
Charging mixer, 130 da. @ $4.00	1,560	8,840	1,040	1,040
Curing concrete, (4), 130 da. @ $4.00	2,080	2,080	2,080	2,080
Trimming subgrade, 130 da. @ $4.00	1,040	6,240	6,240	6,240
Pipe men, 130 da. @ $4.00	520	520	520	520
Fuel for mixer, 130 da. @ $5.00	650	650	650	650
Fuel for roller, 130 da. @ $5.00	650	650	650	650
Gas & oil, finish. mach. 130 da. @ $1.50	195	195	195	195
Gas for pump, 130 da. @ $2.00	260	260	260	260
Lay & remove pipe, (10 mi.) @ $100.00 per mile	1,000	1,000	1,000	1,000
Water boy, 130 da. @ $2.00	260	260	260	260
Sub-foreman on subgrade, 130 da. @ $6.00	.....	780	780	780
Foreman, 7 months, @ $200.00	1,400	1,400	1,400	1,400
Total, labor & fuel	$18,409	$31,669	$23,219	$23,219
Plant charge, mixer @ 42%	3,328	3,328	3,328	3,328
" " , finisher @ 52%	936	936	936	936
" " , subgrader @ 42%	252	.....	.....	.....
" " , forms @ 87%	1,587	1,587	1,587	1,587
" " , pump @ 35%	525	525	525	525
" " , pipe @ 46%	1,602	1,602	1,602	1,602
" " , tarpaulin @ 100%	648	648	648	648
" " , barrows 100%	.....	100	.....	.....
" " , roller @ 25%	1,000	1,000	1,000	1,000
	$ 9,878	$ 9,726	$ 9,626	$ 9,626

	COMPLETE OR COMBINED RWY.	5 TON TRUCK HAND CHARGE	DIRECT CHARGE	FORD TRUCK
10% material loss, @ $3.00 cu.yd.	......	$ 6,720	......	......
Extra concrete, inaccurate subgrade, @ $20 cu.yd.	......	6,000	$6,000	6,000
Load & unload 56 tons, @ $2.00	112	112	112	112
Freight on 56 tons, @ $0.44 cwt.	493	493	493	493
	$ 605	$13,325	$6,605	$6,605
Total, mixing & placing; labor, fuel & plant	$28,892.	$54,720	$39,450	$39,450
Cost per square yard	$ 0.34	$ 0.64	$ 0.46	$ 0.46

The cost shown in the foregoing table is by no means the final cost, as no allowance has yet been made for overhead, bond, workmen's compensation, public liability, contingencies, profit, etc. After all these factors have been properly considered, the allowance for profit being 15 per cent to 20 per cent, the bid price,including material,should be about 35 per cent to 40 per cent in excess of the estimated cost of labor and material. In other words after the cost of labor and material has been estimated, the factors of contractors bond, workmen's compensation, overhead, profit, profit, etc. will increase the cost by approximately 35 to 40 per cent. A short cut method of quickly estimating the bid price after the cost of material and labor has been estimated, is to add 35 to 40 per cent to the latter cost. The percentage to be added to the estimated cost of labor and material in order to secure the bid price will vary with different contractors, but the percentage mentioned in this paragraph is about what conservative contractors figure on.

It must be distinctly understood that the data given in the foregoing tabulations is merely an estimate, and not actual cost data. This estimate, however, is in accordance with conservative practice, but naturally each man will have his own ideas concerning prices. The estimate shown above is based upon normal conditions of 20 working days per month,and fairly reliable railroad service. An unusually good or bad season would probably change these figures considerably.

CHAPTER XIII.

THE ADVANTAGES AND ECONOMIES OF LIGHT RAILWAY HAULAGE

To charge a 4 bag batch of material for a 1-2-3 mixture into a paving mixer by means of wheelbarrows and shovels, requires the following minimum organization:

3 -	men handling cement
1 -	man handling empty bags
4 -	men wheeling stone
3 -	men wheeling sand
4 -	men shoveling stone
2 -	men shoveling sand
17 -	men

The direct charging of the mixer from railway cars, by means of a small derrick attached to the mixer, requires only 3 men, thus effecting a saving of 14 men over the method of charging by hand. At $4.00 per day this saving amounts to $56.00, or to $1,232.00 per 20 day month, allowing pay for 2 rainy days. Inasmuch as the average rate of operation for a 14-E paving mixer has been taken at 1.25 miles of road per month, the saving in labor in charging the mixer effected by the railway method over the hand method amounts to about $1,000.00 per mile. If the monthly output of the mixer is less than 1.25 miles, the saving in labor per mile in charging will be even greater. It is difficult to get men to perform the heavy labor of charging a paving mixer by means of wheelbarrows and shovels. The elimination of this heavy labor, due to direct charging of the mixer, has been known to decrease the labor turnover quite materially. Aside from the actual financial saving, a reduction of 14 men in the size of the gang required is always worth while due to the greater independence from the labor market resulting therefrom.

BATCH BOX CHARGING SYSTEM

If the mixer is charged direct from motor trucks equipped with a special dump body, or a regular dump body subdivided into compartments, 2 men will be required at the charging end of the mixer, providing the batches in the motor truck contain cement. In some states specifications prohibit the dumping of cement in with the sand and stone, and require a special weather tight compartment for the cement. Inasmuch as the special dump bodies with which motor trucks are equipped are generally not divided into separate cement compartments, it becomes necessary to haul out cement in bags and empty it into the mixer by hand. In such a case it is necessary to provide at least 2 more men, making a total of 4 in the charging crew when the mixer is charged direct from motor trucks.

One of the most difficult and expensive operations in road building is trimming the subgrade by hand, and seldom is the cost less than \$0.10 to \$0.15 per square yard. The inexperienced contractor under-estimates the cost of trimming subgrade by hand more frequently than any other item, and there is hardly a contractor who does not suffer loss in this operation. The price for grading is generally adequate only for moving the earth, and all too frequently the profits from earth moving are absorbed in the cost of fine grading. The contractor who has had experience only in rough grading, seldom appreciates the cost of the fine grading involved in preparing a subgrade for a highway. The Lakewood Engineering Company, of Cleveland, Ohio, now manufacture a machine for trimming subgrades. This machine is adjustable with respect to the depth of cut, and inasmuch as it operates on the side forms, it is possible to secure a subgrade almost as accurate as the surface of the finished pavement. The road roller, or a light tractor, is generally used to pull the subgrader. The cost of trimming the subgrade by machine is about \$0.04 per square yard, thus effecting an economy over hand trimming of about \$0.06 per square yard, or \$635.00 per mile of 18 foot road. Machine trimming of the subgrade is feasible only on an unobstructed subgrade, such as that which characterizes light railway haulage.

UNOBSTRUCTED SUBGRADE PERMITS MACHINE TRIMMING

When hauling is performed over the subgrade by means of team or truck it is generally necessary to retrim a considerable proportion of it, and after a rain it is generally necessary to retrim all of the subgrade. If only one-fourth of the area must be retrimmed, the cost, at \$0.10 per square yard, would

amount to $265.00 per mile of 18 foot road. Light railway haulage avoids the necessity for retrimming subgrade because no hauling is done over it, and the subgrade, once finished, need not be touched again.

RETRIMMING SUBGRADE DUE TO TRUCK HAULAGE

Motor trucks are quite commonly used in certain parts of the country, to charge the mixer direct, as illustrated on page 8 and page 93. While this method avoids placing material on the subgrade it cuts up the subgrade quite badly, and wet subgrade results in serious delay. Where weather and subgrade conditions are ideal this method works very well, but it does not possess the reliability or economy of operation of light railway haulage, or combined light railway and motor truck haulage where the trucks operate over the finished pavement.

RUTTED SUBGRADE DUE TO TRUCK HAULAGE

Not only is hand trimming troublesome and expensive, but it is inaccurate. Seldom is a subgrade trimmed by hand accurate to within 1/4 inch of the correct contour and elevation, particularly if the subgrade is crowned. Under the rigid inspection characteristic of road building today hand trimmed subgrade is generally low, and the experienced contractor always makes allowance for this. Loss due to low subgrade is considerably greater than casual consideration would indicate, for a subgrade 1/4 inch too low requires 75 cubic yards of extra concrete per mile of 18 foot road for which no pay is received. At $18.00 per cubic yard, the loss would amount to $1,320.00 per mile. If only half the subgrade is 1/4 inch low or the entire subgrade averages 1/8 inch low, the loss due to extra concrete will still amount to the very considerable figure of $660.00 per mile.

TRIMMING SUBGRADE BY HAND

The State of Pennsylvania has cut a large number of 4 inch diameter cores from roads all over the state, and the majority of these cores indicate that the contractor has placed at least 1/2 inch more concrete than he was paid for. In certain localities loss due to low subgrade might be balanced by the saving effected in high spots, but a contractor contemplating work in states with well organized highway departments will show wisdom by not expecting to compensate his loss from low subgrade by leaving high spots. The tendency in highway engineering is to pay much stricter attention to the subgrade than heretofore, and there is but little chance of a contractor's being permitted to leave a subgrade high. Loss due to low subgrade is one of the most common in highway construction, and is one of the most difficult to overcome. Machine trimming of the subgrade will insure accuracy, and this is one of the big advantages of light railway haulage. The photograph on the following page illustrates a machine trimmed subgrade.

When material is dumped on the subgrade, a very considerable loss occurs due to the mixing of dirt with it, grinding material into the subgrade by the wheels of vehicles employed in hauling it, the effect of weather, and inaccurate placing. When material is dumped on the subgrade in long windrows for a mile or so it remains there for about a month, and the loss which is liable to result is apparent. The accurate placing of material on the subgrade is very difficult. In case insufficient material has been distributed a long wheelbarrow haul is involved, with consequent increased cost and decreased output, until more material

p. 1

can be hauled in over the piles already in place. This is a very difficult proceeding,and the effect on the material already in place needs no comment. In order to provide against delay due to insufficient material a surplus is frequently provided, though this surplus very often occurs unintentionally due to inaccurate distribution. When a surplus of material occurs there are generally no facilities for removing it without seriously delaying the concrete mixer, and the cheapest thing to do is to throw it onto the shoulder. Material so placed on the shoulder is wasted, because by the time the pavement is sufficiently cured to permit traffic it has become dirty and the cost of reclaiming it is more than it is worth. When we consider all these factors and the fact that failure to scrape up the last half inch at the bottom of a pile dumped from a truck or a wagon involves a loss of approximately 5 per cent, it is apparent that a loss of 10 per cent due to dumping material on the subgrade is quite likely to occur. Experienced contractors, when employing the method of dumping material on the subgrade, make an allowance for loss of approximately 10 per cent. A loss of 10 per cent of sand and stone would amount to about $1,000.00 per mile of 18 foot road, if the cost of the material on the road is only $3.50 per cubic yard. Direct charging of the mixer by light railway or motor truck haulage, will eliminate this loss.

MACHINE TRIMMED SUBGRADE

The central unloading and proportioning yard characteristic of railway haulage, is very well adapted to the use of bulk cement. Bulk cement is quoted at $0.05 per barrel less than bagged cement by practically all cement companies, and the final saving due to elimination of lost bags, etc. should amount to some $0.15 per barrel over bagged cement. On a mile of 18 foot concrete road, the saving due to bulk cement at $0.15 per barrel will amount to about $560.00. Bulk cement might be used when mixers are charged direct by motor trucks, but motor trucks seldom possess separate water tight compartments for the cement and many states will not permit the cement to be mixed with the sand or stone enroute to the mixer. In case bagged cement is used, the central unloading and proportioning plant will effect a considerable economy due to reduction in lost and wet bags. A loss of 5 per cent can easily occur when bags are hauled out on the road, and at $0.25 per bag this loss amounts to about $190.00 per mile of road. With a central unloading and proportioning yard, the bags need never leave the cement shed.

LOST MATERIAL RESULTING FROM DUMPING ON GROUND

Inability to operate over wet subgrade is one of the most serious handicaps to road building, when a system is used which involves hauling over the subgrade. Just what delay due to wet weather means in dollars and cents to a contractor is difficult to say, but it can easily mean the entire difference between profit and loss or between finishing a job the current season or carrying it over the winter to the next year. This latter possibility is a very serious one, and a contractor should do everything possible to avoid it. During a normal season bad weather is generally the greatest risk with which a contractor must contend, and anything which will minimize this risk is of paramount importance. Complete light railway haulage, or the combined light railway and motor truck system, will reduce delay from rain to a minimum, as well as permit work to be started earlier in the spring, than if a method of operation is used which involves hauling over earth roads. There are no general figures available showing the increased seasonal output resulting from the use of light railway haulage, but it is understood that in Pennsylvania contractors so equipped have produced an appreciably greater mileage of road than those who hauled over earth road.

When a system of haulage is used which does not permit material to be hauled past the uncured concrete, it is necessary to delay starting the concrete mixer until all, or a considerable proportion, of the grading between the material yard and the far end of the road is complete. Sometimes it is possible to haul thru the grading operations, or around them on a side road. The difficulty of hauling thru grading operations in case of wet weather, or in case of heavy cuts and fills, needs no further comment. Good side roads are very difficult to find, and, when they do exist, the length of haul is generally considerably increased thereby. If the road is constructed in an entirely new location, it is generally necessary to delay concreting until all of the grading has been finished. In most cases when team or truck haulage is used, the concrete mixer cannot be started until all of the grading between the material yard and the far end of the road has been finished. When concreting is finally started, it is necessary to start at the point of maximum haul, when material is hauled by team or truck. Not only is considerable delay incurred, but the only payments received from the state for the first few months are for grading. When concreting is finally started minimum payments for this class of work will result, due to the fact that the most expensive portion, the long haul portion, is done first. The inexperienced organization is

called upon to do the most difficult part of the work first, and is further handicapped by the many chances for delay involved in the long haul over the earth subgrade.

When light railway haulage is used, either by itself or in conjunction with motor trucks, it is possible to start the mixer at the point of minimum haul, because hauling can be carried on, past the uncured concrete, on the shoulder of the road. The concrete mixer can thus be started as soon as a few hundred feet of subgrade have been prepared, eliminating the delay which is generally necessary when a type of haulage is used which cannot operate past the uncured concrete. The placing of concrete and grading is carried on simultaneously, and the most profitable portion of the concrete, the short haul portion, is done first. All this insures a large payment from the state early in the life of the job, thus providing working capital which is generally so urgently needed at this time. This plan of operation also insures that all of the track is well bedded and the organization experienced, by the time the long haul portion of the work is reached. The most critical time in the life of a job is at the beginning, for then everything is literally going out and nothing coming in. The most difficult problem with which the majority of contractors have to contend, is to finance the operation until payments from the state are sufficient to carry the job. Lack of working capital at the beginning of a job is a common source of embarrassment to many contractors, and many failures result, not from low bid prices, but from lack of money during the first few months. In the opinion of many contractors, the biggest advantage of light railway haulage is the fact that it enables the concrete mixer to start at the point of minimum haul with but little delay, and permits simultaneous performance of concreting and grading.

The light railway haulage system, whether used by itself or in conjunction with motor trucks, requires fewer men than any other system. Not only are fewer men required, but the operation of this system appeals to the mechanical instinct in most men with the result that they become interested and attached to their work. Heavy labor is eliminated, and a premium placed upon intelligence and skill. In many instances, the adoption of light railway haulage has resulted in a decreased labor turnover.

LIGHT RAILWAY HAULAGE ELIMINATES HEAVY LABOR

CHAPTER XIV.

THE MINIMUM SIZE OF JOB JUSTIFYING A LIGHT RAILWAY PLANT

A complete light railway road building plant is a comparatively expensive proposition, and while there is practically no limit to the maximum size of job to which it can be applied there is a limit to the minimum size of job on which it is economically justified. This limitation applies to equipment of all kinds, but especially to light railway equipment which, unlike teams or motor trucks, cannot generally be rented and must be purchased. When light railway equipment is rented, the rental charge is so high that it is cheaper to purchase it. While a light railway plant will effect the same economies on a small job as on a larger one, the plant charges on a small job might be such as to absorb all of the economies effected, thus leaving no economic justification for the investment. The purpose of this chapter is to determine, in a general way, the minimum size of job which will justify investment in a complete light railway road building plant.

Investment in a light railway road building plant, or in any other plant, is economically justified when the net savings effected by that plant over other methods is such as to give a satisfactory return on the additional investment, if any, necessary to secure such a plant. The solution of this problem thus hinges largely upon the question of what is considered a satisfactory return on the investment, and naturally this will vary with circumstances and individual judgment. What one man, under certain conditions, considers a satisfactory return, might be considered entirely inadequate by another. Some men might invest in a complete railway plant for a certain job, even though this plant will not yield a greater net return on this particular job than a cheaper plant, because they intend later on to apply it to another job which will justify the investment. It is thus apparent that a large number of opinions prevail as to the minimum size of job which will justify a plant. In this thesis, however, we will assume that a light railway plant is justified,when the net saving effected amounts to 20 per cent of the increased cost over some other type. If a net return of less than 20 per cent is considered satisfactory, the investment can be justified on a smaller job.

Another factor which affects this problem very materially, is the proportion of yearly plant charges assigned to each job. If a contractor has only one job, this job, no matter how small, must carry all of the yearly plant charges. If a number of small jobs are available, however, so located that one plant can be applied to each in turn, it is possible to justify the investment on a smaller job than if only one is available. It is principally when considering the initial investment, that the question of the minimum size of job which will economically justify a certain plant is of importance. After the plant has been purchased it will undoubtedly be applied to jobs of all sizes, because plant charges are almost as great on an idle plant as on a busy one.

The economies which the light railway system of road building will effect over the old system of dumping material on the subgrade and charging the mixer by hand, has been discussed in detail in the preceeding chapter. For convenience, these economies will be summarized below:

Saving in labor in charging mixer..............	$1,000.00
Saving in labor in trimming subgrade............	635.00
Saving in labor in retrimming subgrade..........	265.00
Elimination of lost material....................	1,000.00
Elimination of extra concrete...................	660.00
Saving due to use of bulk cement................	560.00
Saving per mile	$4,120.00

On the average small team or truck job, a portable bin equipped with a bucket elevator or an elevating skip is used for unloading material from railroad cars and loading into trucks or wagons. A bin of this type is illustrated on page 82. Such a bin, of 50 ton capacity, costs about $1,800.00. A crane equipped with a 3/4 yard clam shell bucket, such as is commonly used in unloading material for a light railway plant, costs about $10,000.00. On the average small job, material is stored on the subgrade in windrows, and in order to store the same quantity insured by a tunnel 150 feet long it is necessary to place material on the subgrade for a distance of 1 mile. Very seldom is material stored on the subgrade for more than a mile ahead of the mixer, so in making our comparison we will assume a tunnel 150 feet long. Such a tunnel, equipped with traps every 8 feet, will cost about $2,000.00. The cost of the unloading equipment required by a light railway plant, will, therefore, exceed that commonly used on a small team or truck job by some $10,200.00. Considering everything, the unit cost of unloading will not differ greatly with either method.

In computing the cost of haulage, it will be assumed that teams are hired for $10.00 a day and 5-ton motor trucks for $40.00 a day. The railway equipment will be proportioned for three-fourths of the maximum haul, and all the plant charges for the year will be assigned to the particular job in mind. The rate of operation of a 14-E paving mixer, will be taken at 1.25 miles of 18 foot concrete road per 20 working day month. The type of road will be assumed to be concrete, 18 feet wide, with an average thickness of 7-1/3 inches and proportions of 1-2-3. The length will be taken at 5 miles.

At a rate of 1.25 miles per month, approximately 4 months will be required to place the concrete on this road. Due to the greater possibility of delay from rain when material is hauled over the subgrade by teams or motor trucks, it would seem to be reasonable to assume the output of the mixer at 1 mile per month. In making our comparison, however, the greater possibility of delay from rain when team or truck haulage is used will be ignored, but an allowance of pay for 10 per cent of the time due to rainy weather will be made.

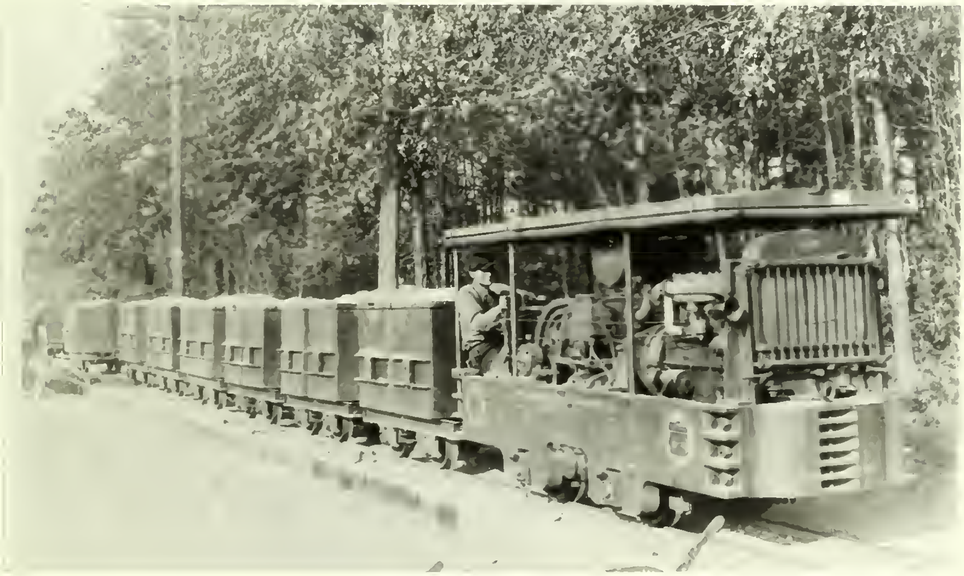
The quantity of material needed in a road of this type and length, based upon weights of 376 pounds per barrel of cement, 3,000 pounds per cubic yard of sand, and 2,700 pounds per cubic yard of stone, is as follows:

18,850	bbls. cement	or	3,544 tons
5,600	cu.yds. sand	or	8,400 tons
8,400	cu.yds. stone	or	11,340 tons
			23,284 tons

On the average haul of 2-1/2 miles, a team will make a round trip under good conditions in 130 minutes or 4-1/2 trips per 10 hour day. This is at a speed of 2-1/2 miles per hour, allowing 5 minutes for dumping and 5 minutes for loading. To deliver the total of 11,600 team loads of 2 tons each, will thus require 580 team days.

A 5 ton motor truck should operate at a speed of 6 miles per hour loaded and 10 miles per hour empty over earth subgrade, with an allowance of 5 minutes for loading sand or stone and 10 minutes for dumping and getting away. An allowance of 20 minutes for loading a 26 barrel load of cement and the same amount of time for unloading, should be made. On the average haul of 2-1/2 miles, therefore, a truck should make 11 round trips per day hauling sand or stone, and 7 round trips hauling cement. A total of 465 truck days are thus required to haul the 4,660 loads of 5 tons each.

Based upon a haul of 3.75 miles and a speed of 6 miles per hour, allowing 5 minutes for switching trains at the mixer and 5 minutes at the material yard, a locomotive should make a round trip in 85 minutes. This is at the rate of 7 round trips per 10 hour day, so that 1 locomotive hauling a 7-car, 14-batch, train should deliver 98 batches to the mixer. Three 6-ton locomotives and 5 - 7-car trains are thus required. The amount and cost of the railway equipment is shown below.



BURTON 6 TON LOCOMOTIVE HAULING 8 CAR TRAIN

EQUIPMENT		COST	
5.25 miles track	@	$ 6,318.40	$ 33,171.60
12 half turnouts	@	150.00	1,800.00
24 curved sections	@	13.95	334.80
3 6-ton locomotives	@	4,600.00	13,800.00
70 batch boxes,25 cu.ft. cap.		71.20	4,984.00
35 batch box cars	@	115.00	4,025.00
			$ 58,115.40

The cost of operation of the three systems considered, should be about as follows on this particular job, allowing pay for 10 per cent lost time due to rain to the hired teams and trucks:

			RAILWAY	TEAM	TRUCK
3 loco. operators, 4 months	@	$120.00	$1,440	.....	.....
3 train men, 80 days	@	4.00	960	.....	.....
Gas & oil, per loco. 90 days	@	5.00	1,350	.....	.....
Lay & remove 7 mi. track	@	200.00	1,400	.....	.....
Plant charge on track	@	30½%	10,768	.....	.....
Plant charge on locos	@	52 %	7,176	.....	.....
Plant charge, cars and boxes	@	34 %	3,063	.....	.....
Load & unload 381 tons equip.	@	2.00	762	.....	.....
Freight, per cwt.	@	0.44	3,353	.....	.....
Rental of teams,	@	10.00	.....	$28,380	.....
Rental of trucks	@	40.00	.....	.....	$20,460
			$30,267	$28,380	$20,460

The cost of operation by the railway method,on this particular job, is estimated to exceed the cost by teams by $1,887.00,and the cost by trucks by $9,807.00. The initial investment in the railway hauling and unloading plant exceeds that in the team or truck plant, which is merely hired by the day, by $68,315.00. The saving effected by the railway plant has previously been shown to be some $4,120.00 per mile, over the team or truck system where material is dumped on the subgrade and charged into the mixer by hand. The total saving on this job would, therefore, amount to approximately $20,600.00. Subtracting the increased cost of operation by the railway method leaves a net saving of $19,738.00 over the team method, and $11,818.00 over the truck method. These savings amount to 29 per cent and 19 per cent,respectively,of the additional initial investment of $68,315. in the railway plant over the other methods of doing the work.

We have previously assumed that a net return of 20 per cent on the additional investment is sufficient to justify a complete railway plant. Inasmuch as this assumption was arbitrary, it seems safe to say that, with the unloading point at one end and material dumped on the subgrade, a complete railway plant can be economically justified on a 4-1/2 mile job, when compared with team haulage, and on a 5 mile job when compared with truck haulage. This comparison is made with teams and trucks hired by the day. If the contractor owned the teams or trucks he would be compelled to consider plant charges on them,and the railway plant could be justified on a smaller job than those indicated above,inasmuch as the difference in the initial investment in these several plants would be greatly reduced.

By proceding in the manner outlined in the foregoing, a complete railway plant can be shown to be economically justified over a hired team or motor truck plant on a 3-1/2 or 4 mile job, when the unloading point is near the middle of the job and immediately adjacent to it,or up to 2 miles away. In the same manner it is possible to show that a combined light railway and motor truck plant, in which the trucks are hired at the rate of $40.00 per day, can be justified on a job 2-1/2 to 3 miles in length,when compared with a hired team or truck plant dumping material on the subgrade.

\- All of the foregoing is based upon the assumption that the entire yearly plant charges must be absorbed by only one job. If more than one job is available, so that a portion of the plant charges can be assigned to each, it is apparent that investment in a complete railway plant can be justified on a considerably smaller job than if one job alone must carry the entire plant charge. If a rate of return of less than 20 per cent on the additional initial investment required

for the railway plant is considered satisfactory, investment in a railway plant can be justified on smaller jobs than those indicated above.

Other factors besides the strictly financial one must sometimes be considered, when deciding whether or not a certain job will justify investment in a railway plant. The difficulty of securing labor or of starting work early in the spring, might be such as to induce a contractor to use a railway plant when perhaps it might be more economical, under normal conditions, to use some other method.

In making the comparison between the railway plant and the team or truck plants, we have practically placed them all on the same basis as far as reliability of operation is concerned. If weather and soil conditions are good this assumption might be correct, but during a wet season and in certain soils there is no doubt but that the railway system would possess big advantages over the other systems. Furthermore, the team and truck equipment was based upon the average haul, while the railway equipment was based upon three-fourths of the maximum haul. At points beyond the average haul, therefore, the team or truck equipment provided would not have sufficient capacity to keep the mixer going at its maximum rate. All these factors must be kept in mind in deciding upon the minimum size of job which will justify investment in a complete railway plant, and the financial factor, while admittedly of great importance, is not the only one to be considered. Each job possesses its own peculiar factors, and must be studied by itself. In the absence of specific knowledge concerning local conditions, and for general use, the determination made in the preceeding paragraphs can be used as a guide. As previously stated a determination of this kind is of importance principally when considering the initial investment, for after the equipment has been purchased it will undoubtedly be used on jobs of all sizes.

A comparison of a light railway, or a combined light railway and motor truck system, with any other method, can be made in the manner outlined in this chapter.

CHAPTER XV.

PRESENT TENDENCIES IN HIGHWAY CONSTRUCTION.

Until a few years ago highway construction has been considered a small man's game, in fact the building of highways was more or less sporadic with no serious attempt at quantity production. The equipment used had been developed more or less by rule of thumb, and was not really capable of producing roads in large quantity. No real attempt had been made to produce high class,labor saving equipment, and the type of equipment used and the methods employed varied with practically every contractor. The organization for building highways was not well developed or efficient, and the quantity and quality of the roads was of corresponding character. Contracts were awarded for such small sections as to preclude the use of any considerable amount of labor saving equipment, or to attract the attention of large contracting organizations.

About two years ago a radical change was effected in the highway construction field, in answer to the great demand for good roads which the war developed, or at least accelerated. A number of equipment manufacturers for some years previously had been working on a theory that methods of highway construction then in use were bound to be superseded by more efficient methods, and had designed greatly improved machinery. They foresaw that in order to build the mileage of good roads necessary in this country, the production of good roads must be greatly increased. In order to effect this increase it was necessary to award large contracts, and to introduce methods common to other large construction projects. Large contracts naturally attracted larger organizations, whose experience and financial resources were such as to warrant the building of high class road construction equipment intended for quantity production.

About this same time the highway engineering profession thruout the country realized, as the result of heavy motor truck traffic incident to war work, that our trunk line highways must be made considerably heavier and better. Heavier construction naturally involves a greater amount of labor, and labor saving equipment, therefore, was in demand. The shortage of labor which has prevailed thruout the country ever since the war began, except during the winter of 1920-21, was another incentive for adopting labor saving equipment.

Not only must our roads be made heavier but they must be made better, and highway engineers are today devoting more time and study to the details of construction than ever before. In order to increase the quality of our roads it was necessary to eliminate many of the uncertainties which, up to the present time, have characterized highway engineering. The research work of Professor Duff Abrams at Lewis Institute, Chicago, during the past six years, has demonstrated that a large proportion of the potential strength of concrete is wasted by the use of an excessive amount of water. For some years highway engineers had realized that the use of too much water was a detriment to the quality of the road, but they were forced to compromise on account of the limitations imposed by hand construction methods. The finishing machine, which subjects the concrete to a thoro tamping action, enabled highway engineers to employ dryer mixtures in accordance with the discoveries of Professor Abrams. That this results in improved quality has been demonstrated by tests on cores from both hand and machine finished concrete roads, which have been cut out and tested by the Pennsylvania and Illinois Highway Departments.

For years highway engineers have attempted to secure a smooth, uniformly compacted subgrade, but with hand construction methods this has been practically impossible at a reasonable cost. A machine for trimming subgrade, illustrated in the foregoing pages, is now on the market. This machine is no doubt but the forerunner of much more elaborate and efficient machines in the future. Not only does machine trimming of the subgrade assure the highway engineer of the desired smoothness in the subgrade, but it eliminates a lot of trouble and expense to the contractor. Machine trimming of the subgrade should result in both improved quality and decreased cost of our highways.

Highway engineering to date has really been more of an art than a science. But little attempt has been made to discover the reasons for certain practices which have prevailed for years, and highway construction has largely been covered by precedent. At the present time highway engineers are realizing that a vast and practically untouched field of research is open to them, and the demand of modern heavy traffic and anticipated future traffic has forced them to acknowledge that our present knowledge of highways and highway construction is inadequate, to say the least. The leading highway departments have established laboratories whose function is not merely to conduct routine tests on materials, but to carry out field investigations on a large scale. In order to obtain knowledge of material as it exists in the finished pavement, many highway departments have equipped themselves with core drilling outfits. With these outfits cores are cut from existing pavements of all kinds, and special attention can be given to roads or portions of roads which have failed. These investigations promise to yield valuable results during the next decade.

Not only can experiments be carried out on cores cut from roads, but much valuable data can be gained from a study of subgrade conditions. Heretofore our knowledge of subgrade conditions has been very meager, and has been largely theoretical. The possibility of studying the subgrade in order to determine the relative amount of frost and moisture under the center of the road and at the shoulders, the bearing power at different seasons of the year, etc. is being realized by many highway departments, and should yield valuable results.

The great "unknown" in highway engineering today, as in the past, is the subgrade. Heretofore subgrade has been taken for granted as found, and but very little attempt has been made to modify existing conditions so as to secure a subgrade of the proper character. True, the necessity for drainage has long been realized, but the provisions for drainage were largely based upon precedent and were more or less superficial and inadequate. Highway engineers have not looked at the problem of drainage from the same point of view as the drainage engineer, and tile of a certain size has been placed in a certain position, irrespective of the character of the soil, just because that particular practice had always prevailed. The same type of pavement and the same type of drainage were used in all localities, and in all soils. The attitude of highway officials, who were not engineers, and of the public, which demanded the greatest mileage of improved road for its money, was no doubt largely responsible for the neglect of proper attention to subgrade conditions. Money placed in a drainage system is not apparent on the surface and is not as effective for political purposes, as an increased mileage of pavement. In spite of all this, however, the highway engineer is somewhat to blame for not insisting more firmly on proper preparation of the foundation. At the present time the sentiment is rapidly growing among the highway profession that the most important factor in the success of a road is a proper foundation, in fact it is hardly too much to say that a good road consists primarily of a properly designed drainage system surfaced with some type of material which will resist distortion and abrasion fairly well. Drainage systems will no

doubt become more elaborate as time goes on, and the system employed today will probably seem rather puny and inadequate by comparison.

The United States Office of Public Roads, the Federal Highway Council, which is affiliated with the National Research Council, and all the leading State Highway Departments are now carrying on extensive investigations of soil physics and methods of properly preparing and maintaining the foundation for a road. All of these efforts should produce valuable information during the next decade, and our present conception of proper highway construction will no doubt be changed considerably. The tendency of the day is toward intensive study and research, in order to make of highway engineering more of a science and less of an art than it has been heretofore.

Up to the present time most of the research work on highway construction methods and material has been carried on by commercial organizations who were financially interested in the subject, and highway engineers have been prone to accept the results of these investigations without taking it upon themselves the responsibility for research work. Happily highway engineers are now realizing that the responsibility of carrying on research work for improving types of road and methods of construction is theirs, and they are beginning to assume their rightful leadership in this field.

Until quite recently highway engineers have concerned themselves almost entirely with the technical details of road building, and have paid but little attention to construction methods. Engineers now realize that the method of construction used will influence the quality of a road very considerably, and they are now giving some attention to this important feature instead of leaving it entirely in the hands of the contractor or his superintendent. Many State Highway Departments now prohibit dumping material on the subgrade in order to avoid the possibility of dirty material, and to eliminate the rough subgrade which such a practice produces. The State of Pennsylvania, for instance, in its 1921 specifications will permit material to be dumped on the subgrade only in piles not less than 1,000 feet apart, provided that 500 feet of subgrade in advance of the mixer is at all times kept entirely free from obstruction. The State of Kansas permits material to be dumped only on the shoulders of a road, and only then on planks. The States of Iowa and Illinois have somewhat similar provision. Undoubtedly in a short while highway engineers will entirely prohibit hauling over the subgrade, in order to eliminate the roughness and the non-uniform compactness resulting therefrom. The tendency is for highway engineers to interest themselves in the methods of construction used, realizing that only by using proper methods can full benefit be obtained from the precautions they take with respect to quality of material.

Improper attention to maintenance and a tendency to use the same type of construction on all roads, has characterized highway engineering very largely in the past. This does not mean that the value of proper maintenance or of adapting various types of construction to different conditions has not been realized, but,if realized, proper steps have not been taken to put this realization into practice. The tendency now is to conserve existing investments in roads by paying proper attention to maintenance, and to devote more study to the problem of selecting the most economic type of road for various localities. It is undoubtedly true that our trunk line system should be constructed in the best possible manner, and in most localities the importance of this system and the amount of traffic it will carry is such as to warrant an expensive type of road. It is just as true, however, that the tendency has been to accept some one type as a

"cure-all", and to use it on all roads irrespective of cost. There is no doubt but that the majority of our secondary roads can be made suitable for the traffic they will be called upon to carry by means of some of the less expensive types of material, ed provid~~ing~~ that proper attention is paid to the location of the road, the profile, and preparation of the subgrade. It is fully recognized that the adoption of a type of pavement on a heavy traffic road merely because of low initial cost is a wrong policy, because the high cost of maintenance will eventually cause an ultimate cost greater than that of some other type of greater first cost. Nevertheless it is believed that expensive roads are frequently used, where a less expensive type would serve fully as well. Highway engineers are now devoting much more thought and study to the economics of their problem than ever before. With proper maintenance methods there is no doubt but that a cheaper type of road, will frequently serve as well as a more expensive type. At the same time we must not overlook the fact that on heavy trunk line highways, the best is none too good.

Considerable delay has been incurred during the past two years, by a shortage of road building material. This has led many highway departments to curtail the building of so-called permanent roads, and to concentrate their efforts on grading, culverts, and bridges. The graded road bed has generally been temporarily surfaced with gravel, to carry traffic for a season or two until conditions permitted the permanent surfacing to be placed. On a heavy traffic road, the economies effected by proper location and grading are no doubt sufficient to pay for the cost of the temporary gravel surface.

One of the most serious handicaps to quantity production of road during the past two years, has been a shortage of road building material. Progressive highway departments have not been content to merely fold their hands and sit back until conditions improved, but have devoted a large amount of time and effort to remedying the situation. This effort has taken the form of comprehensive surveys, in conjunction with the State Geological Department, to locate suitable deposits of road building material. In some states these surveys have resulted in uncovering sufficient deposits of suitable material, to construct a considerable portion of the system. The laboratories established by these highway departments have thus amply justified themselves.

Contractors who are at present being attracted to the highway construction field are a capable and keen lot of men, many of them with engineering training. The type of contractor which modern highway construction is developing is a far sighted, keen, business man, who realizes that the success to be obtained in this field depends upon scientific methods and proper preparation. Instead of depending upon day to day delivery of materials from the railroad with the resultant chance for delay, the modern progressive highway contractor stores material during the inactive months in order that the production of roads can be carried on without delay during the construction season. In this he is being encouraged and assisted by State Highway Departments, most of whom, at the present time, pay for material as it is received at the material yard. The result of this cooperative effort between engineers and contractors, is that the yearly output of road is steadily increasing per mixer. A number of instances of quantity production of roads were given in the early part of this thesis, and, while it is true that they represent peak performances, it is equally true that they indicate the tendency of the time. A few years ago such performances were entirely unknown, even as peak performances, and there is no doubt but that during the next few years they will become common and will be greatly surpassed. These performances indicate what we can expect from the efficient contractor of tomorrow, with his highly trained and highly skilled organization, employing high class labor saving equipment.

Highway departments are gradually realizing the necessity for awarding contracts early, but as yet there is still room for a lot of improvement. A contractor who does not receive his contract until March or April loses a good deal of valuable time during the construction season in getting ready, when that time could be much more profitably employed in actual construction. As a rule he does not order his equipment until he has received his contract, with the result that equipment manufacturers are unable to supply the equipment without delay because of the large demand which occurs at that particular season of the year. The manufacture of highway construction equipment is a difficult problem, because the demand for this equipment is so variable. The heavy demand occurs during the months of March, April and May, with but little demand during the rest of the year. If highway departments would only realize this more fully, they could increase road production very materially by awarding contracts so that the contractor would have ample time to secure his equipment.

In the past the tendency has been to place all the risk for loss in highway construction on the contractor, and the contracts and specifications have been very one sided. The tendency now is for the state to share with the contractor, the risk of performing the work. An instance of this is to be found is the Georgia Highway Department, where Mr. W. R. Neel, State Highway Engineer, has introduced a new form of contract known as Form "B". This contract combines the principles of cost-plus-a-fixed-sum, and competitive bidding. The contractor in submitting his bid divides it into two parts, the estimated cost and the desired compensation. In order to have an incentive to keep down the cost, the contractor is allowed 25 per cent of any saving on the estimated cost, provided it does not exceed 50 per cent of the total compensation in the proposal. Should the cost exceed the estimate, 50 per cent of the excess is deducted from the compensation, with the provision that the compensation must not be reduced more than 75 per cent. The contractor is, therefore, assured of at least 25 per cent of the compensation asked for in his bid. The contract also provides for a machinery and equipment rental, a form being provided which forms a part of the contract cost of work. This rental schedule is fixed, and only interest is allowed on the value of equipment plus a fair rate for depreciation, insurance, and estimated repairs. In this way no profit can be made other than that shown as compensation, and the amount of profit depends upon the skill and zeal used in prosecuting the work. The minimum compensation which a contractor can receive is 25 per cent of that asked for in his bid, while the maximum is 50 per cent in excess of this amount. The tendency in other states is also toward sharing the risks with the contractor, and this should lead to decreased cost of construction.

In the past highway engineers have been all too prone to consider that their problems were the only important problems in highway construction, and they have not shown a tendency to cooperate with contractors and equipment manufacturers in a proper manner. Contractors and equipment manufacturers have been looked upon as more or less necessary evils. Highway engineers should realize that road building is a cooperative problem, and that the manufacturer of equipment and the contractor is important and is entitled to due consideration. Without the equipment manufacturer and the contractor, the highway engineer would probably not make much progress. Happily at the present time everybody concerned is beginning to realize that road building is a cooperative proposition. The sooner this realization becomes general the better it will be for everybody, and the sooner will our desire for an adequate highway system be realized.

A P P E N D I X

M O D E R N   M E T H O D S
O F
H I G H W A Y   C O N S T R U C T I O N

COMPARISON OF FABRICATED TRACK WITH WOODEN TIE TRACK.

GENERAL DATA.

Cost of 20 pound rail - \$2.67 per cwt.
Cost of $\frac{1}{2}$" x 4" straight railway spikes - \$4.25 per cwt.
Weight of $\frac{1}{2}$" x 4" straight Railway spikes - 33.4 lbs. per 100.
Cost of spikes \$0.0142 each, or say \$0.015 on job.
Cost of splice plates and bolts - 50¢ per set.
Weight of " " " " - 4.86 lbs. per set.
Weight of $\frac{1}{2}$" x 2" track bolts - 0.21 lbs. each, or 0.63 for 4.
Weight of two splice plates - 4.03 lbs.
Cost of 3/8" x 3" screw spikes - \$6.03 per cwt. or 1¢ each.
Cost of 3" x 6" x 42" red oak tie - \$0.30 each.
Cost of 4" x 6" x 42" pine tie - \$0.35 each.
Weight of 3" x 6" x 42" red oak tie - 20.25 lbs.
Weight of 4" x 6" x 42" yellow pine tie - 22.4 lbs.
Weight of 4" x 6" x 42" white pine tie - 16.5 lbs.
Cost of forged steel joint clips, designed to eliminate splice plates and bolts, \$0.24 each.
Life of rail and of fabricated track will be taken at six years, with 10% salvage value, in one case, and at four years with 10% salvage value in another.
When the life of rail is taken at six years, it will be assumed that wooden ties are replaced in three years. The wooden ties are assumed to last four years, when the life of rail is taken at this figure.
Two types of wooden tie track are assumed, namely soft wood ties with 4 straight spikes, and hard wood ties with 6 screw spikes.

STRAIGHT SPIKE TRACK, SEVEN TIES PER FIFTEEN FOOT SECTION

\$1,879.68.......cost of rail, at \$2.67 cwt.
862.40.......cost of ties, at \$0.35
150.00.......cost of spikes, at \$0.015, 4 per tie.
352.00.......cost of splice plates and bolts at \$0.50 per set
\$3,244.08.......cost per mile of track

70,400 lbs......weight of rail
55,400 " ......weight of ties, at 22.5 lbs.
3,292 " ......weight of spikes, at 0.334 lbs.
3,422 " ......weight of splice plates and bolts at 4.86 lbs. per set.
132,554 lbs. or 66.28 tons, per mile of track.

COST, SIX YEARS LIFE

$3,244.06.....first cost.
1,012.40.....new ties and spikes at end of 3 years.
515.52.....interest on rails and splices at 3.85% for 6 years.
212.60.....interest on ties and spikes at 3.5% for 6 years.
215.60.....replacement of broken ties, 5% per year.
105.60.....replacement of lost splice plates and bolts, 5% per year.
1,657.00.....freight on 66.28 tons at $0.25 cwt. for five shipments.
12,672.00.....laying and removing at $0.20 per foot twice a year for 6 years.
662.80.....loading and unloading at $2.00 per ton, five times.
$20,297.60.....cost per mile for 6 years.

3,282.93.....gross cost per mile per year.
223.17.....salvage value of rails and splices at 10%
3,059.76.....net cost per mile per year.

COST, FOUR YEARS LIFE

$3,244.08.....first cost
499.59.....interest at $3.85% for 4 years.
147.84.....replacement of broken ties, 5% per year.
105.60.....replacement of lost splice plates and bolts, 5% per year.
994.20.....freight on 66.28 tons at $0.25 cwt. for three shipments.
8,448.00.....laying and removing at $0.20 per foot twice a year for 4 years.
397.68....loading and unloading at $2.00 per ton, three times.
$13,836.99....cost per mile for 4 years.

3,459.25....gross cost per mile per year.
223.17....salvage value of rails and splices at 10%
3,236.08....net cost per mile per year.

SCREW SPIKE TRACK, EIGHT OAK TIES PER FIFTEEN FOOT SECTION

$1,879.68.....cost of rail at $2.67 per cwt.
844.80.....cost of 3" x 6" oak ties, at $0.30
186.00.....cost of spikes, at $0.01, 6 per tie, plus 10% loss.
168.96.....cost of joint clips, at $0.24
$3,077.44.....cost per mile of track.

70,400 lbs....weight of rail
57,024 " ....weight of ties, at 20.25 lbs.
2,800 " ....weight of spikes
2,816 " ....weight of joint clips, at 4 lbs.
133,040 lbs. or 66.52 tons, per mile of track.

COST, SIX YEAR LIFE

$3,079.44.....first cost
1,030.80.....new ties and spikes at end of 3 years.
473.23.....interest on rails and clips at $3.85% for 6 years.
216.47.....interest on ties and spikes at 3.5% for 6 years.
211.20.....replacement of broken ties, 5% per year.
1,657.00.....freight on 66.52 tons, at $0.25 cwt. for 5 shipments.

665.20.....load and unload at $2.00 per ton, five times.
1,056.00.....assembling track at $0.20 per foot.
3,600.00.....laying and removing at $300.00 per mile, twice a year for 6 years.
$11,989.34.....cost per mile for six years.

1,998.22.....gross per mile per year.
204.86.....salvage value of rails and clips at 10%.
$ 1,793.36.....net cost per mile per year.

COST, FOUR YEAR LIFE

$ 3,079.44.....first cost.
474.23.....interest at 3.85% for 4 years.
168.96.....replacement of broken ties, 5% per year.
994.20.....freight on 66.52 tons, at $0.25 cwt. for three shipments.
399.12.....loading and unloading, at $2.00 per ton three times.
1,056.00.....assembling track at $0.20 per foot.
2,400.00.....laying and removing, at $300.00 per mile twice a year for four years.
$ 8,571.95.....cost per mile for four years.
2,142.99.....gross cost per mile per year
204.86.....salvage value of rails and clips at 10%
$ 1,938.13.....net cost per mile per year.

SCREW SPIKE TRACK, SEVEN OAK TIES PER FIFTEEN FOOT SECTION

$1,879.68.....cost of rail, at $2.67 per cwt.
739.20.....cost of 3" x 6" oak ties, at $0.30
100.00.....cost of spikes at $0.01, 6 per tie.
168.96.....cost of joint clips at $0.24
$2,887.84.....cost per mile of track

70,400 lbs....weight of rail.
49,896 " ....weight of ties at 22.5 lbs.
1,867 " ....weight of spikes, four per tie.
2,816 " ....weight of joint clips, at 4 lbs.
124,979 lbs. or 62.5 tons, per mile of track.

COST SIX YEAR LIFE.

$ 2,887.84.....first cost
839.20.....new ties and spikes at end of 3 years.
473.24.....interest on rails and clips at 3.85% for six years
176.23.....interest on ties and spikes at 3.5% for six years.
184.80.....replacement of broken ties, 5% per year.
1,562.25.....freight on 62.5 tons at $0.25 per cwt. for five shipments.
625.00.....load and unload 62.5 tons at $2.00 per ton five times.
1,056.00.....assembling track at $0.20 per foot.
3,600.00.....laying and removing track at $300.00 per mile twice a year for 6 years.
$11,204.56.....cost per mile in six years.

$ 1,867.44.....gross cost per mile per year
204.86....salvage value of rails and clips at 10%
1,662.58....net cost per mile per year.

COST, FOUR YEAR LIFE

$ 2,887.84.....first cost.
444.73.....interest at 3.85% for four years.
147.84.....replacement of broken ties at 5% per year.
937.35.....freight on 62.5 tons at $0.25 per cwt. for three shipments
375.00.....load and unload 62.5 tons at $2.00 per ton, three times.
1,056.00.....assembling track at $0.20 per foot.
2,400.00.....laying and removing track at $300.00 a mile twice a year for four years.
$ 8,248.76.....cost per mile for four years.

$ 2,062.19.....gross cost per mile per year.
204.86.....salvage value of rails and clips at 10%
$ 1,857.33.....net cost per mile per year.

LAKEWOOD PRESSED STEEL TIE TRACK

COST, SIX YEAR LIFE.

$ 6,318.40.....first cost.
1,459.50.....interest at 3.85% for six years.
1,518.00.....freight on 60.72 tons at $0.25 per cwt. for five shipments.
607.20.....load and unload 60.72 tons at $2.00 per ton five times.
2,400.00.....laying and removing track at $200.00 per mile twice a year for 6 years.
1,137.80.....repairs due to straightening bent ties, etc. 3% per year.
$13,440.40.....cost per mile for six years.

$ 2,240.07.....gross cost per mile per year.
631.84.....salvage value of track at 10%
$ 1,608.23.....net cost per mile per year.

COST, FOUR YEAR LIFE.

$ 6,318.40.....first cost.
973.03.....interest at 3.85% for four years.
910.80.....freight on 60.72 tons at $0.25 per cwt. for three shipments.
364.32.....load and unload 60.72 tons at $2.00 per ton three times.
1,600.00.....lay and remove track at $200.00 per mile twice a year for 4 years.
1,137.30.....repairs due to straightening bent ties, etc., 3% per year.
$11,303.85.....cost per mile for four years.

$ 2,825.96.....gross cost per mile per year.
631.84.....salvage value of track at 10%.
$ 2,194.12.....net cost per mile per year.

The rate of interest is taken at 7%, and is figured on the depreciated value at the end of each year. This results in an average rate of 3.85% where the equipment has a 10% salvage value, and 3.5% where it has no salvage value. Equipment having a salvage value at 10% has an average value throughout its life of 100% plus 10%, divided by 2, or 55%. Multiplying the average value of 55% by the

interest rate of 7% gives an average interest rate of 3.85% etc. This is in accordance with the methods recommended by the Associated General Contractors.

Of the foregoing assumptions, perhaps that of assigning a six year life to the rail and to the Lakewood track and replacing the ties at the end of three years is most nearly correct. While there is no experience to the contrary, it is believed that the assumption that wooden ties will last four years when the life of the track is taken at this figure is somewhat optimistic.

When oak ties and screw spikes are used, it is assumed that the track is not dismantled from year to year. When soft wood ties and straight spikes are used, it is assumed that the track is dismantled at the end of each season.

ITEMS ENTERING INTO COST OF HIGHWAY CONSTRUCTION

WISCONSIN STATE HIGHWAY DEPARTMENT

(From Engineering News-Record - April 1, 1920)

1 - MOVING EQUIPMENT

Hauling from shed to cars
Loading
Freight charges
Cost of unloading
Moving to job
Lost time of equipment
Erection of camp including water supply
Transporting teams or trucks
Return of above

2 - COST OF RENTAL OF R. R. SIDING

3 - CEMENT, COST PER BARREL, F.O.B. CARS AT

Number of barrels
Unloading and storing
Hauling and covering
Fire insurance on cement and empty sacks
Sack loss 2% to 5%
Freight return of empty sacks
Demurrage

4 - FINE AGGREGATE

Number of cubic yards, including waste
Average price per cubic yard, f.o.b. pit or quarry
Freight and demurrage
Labor - unloading
Hauling to job
(Labor and horses)
Spotting on job
Rehandling from stock pile

5 - COARSE AGGREGATE

Number of cubic yards, including waste
Average price per cubic yard, f.o.b. pit or quarry
Freight and demurrage
Labor - unloading
Hauling to job
(Labor and horses)
Spotting on job
Rehandling from stock pile

6 - SURFACING

Rolling subgrade
Joint material delivered on the job

6 - SURFACING (Cont'd)

Labor mixing and placing concrete (including engineer, firemen, form setters, fine graders, wheelers, shovelers, cement men, puddlers, baling and sorting sacks, curing, covering and uncovering, finishers, water boy, watchmen, barricade and lights)

Foreman	days @
men	days @
men	days @
men	days @
men	days @

PUMPING AND WATER SUPPLY

(Labor, connecting pipe, setting pump, operator, fuel, disconnecting pipe and drilling well)
Gasolene, coal, oil, etc.
Hiring, shipping in men and loss in running camp
Purchase of hardware, lumber, boots, etc.
Rent of water, buildings, warehouse, grounds, etc.
Building cross-overs

7 - BREAKING AND MOVING DIRT AND ROCK

Staking
Keeping road open to travel
Clearing
Grubbing
Excavating earth, light, men and teams only
Excavating earth, heavy, men and teams only
Excavating rock, loose, men and teams only
Excavating rock, solid, men and teams only
Dynamite
Sloping
Trimming
Shoulders
Ditching
Moving, enter under No. 1
Equipment, etc., enter under No. 1

8 - CULVERTS AND BRIDGES

Number cubic yards in job
Moving equipment, enter under No. 1
Labor, enter under No. 6
Material, enter under Nos. 3, 4 and 5
Labor excavating, removing of old structures; building forms, removing forms, placing concrete
Detours or temporary bridges
Piling
Cofferdams
Expansion joints
Waterproofing
Drains
Steel
Lumber

9 - GUARD RAILS

Posts
Lumber
Paint
Hardware
Creosote
Labor
Hauling

10 - UNFORESEEN DIFFICULTIES

Delays due to railroad embargoes, strikes at pit or jobs, material plant breakdown, breakdown of machinery, failure of water supply, bad weather, pipe line breaks and freezing.

11 - COMPENSATION AND PUBLIC LIABILITY INSURANCES (LABOR ONLY)

12 - OVERHEAD

Per cent of manager's yearly salary
Per cent of yearly salary of stenographer and clerk
Per cent of yearly salary of material man and timekeeper
Per cent of yearly expense of manager
Auto   Mile at 12¢
(Railroad fare, hotel, meals)
Bidding costs, conventions, associations
Per cent of yearly office rent
Per cent of yearly office telephone and telegrams
Per cent of office supplies, miscel.
Corporation insurance
Interest on borrowed money

13 - BOND COST (PERSONAL OR SURETY)

14 - TOTAL NET COST OF JOB

15 - PROFIT FOR EACH CLASS OF WORK, AS PAVING, GRADING, ETC.

16 - DEPRECIATION ON EQUIPMENT AS LISTED IN TABLE II.

CONSTRUCTION EQUIPMENT RENTAL SCHEDULE

A GUIDE TO ESTIMATING CONSTRUCTION EQUIPMENT EXPENSE, SUBMITTED BY THE COMMITTEE ON METHODS OF ASSOCIATED GENERAL CONTRACTORS

A rental schedule that will furnish contractors with a practical means of estimating equipment expense and determining adequate rental charges was the objective sought by the Committee on Methods in working out a standard schedule for the Association. Such a schedule, evolved from the records and experience of contractors, manufacturers and rebuilders of equipment, has been prepared by the Research Division under the direction of the committee and approved by the Executive Board. It is herewith presented for use in determining rental charges.

To use the schedule with safety, it is essential to understand how the amounts were obtained; how they are to be applied and how they are limited for determining rental charges. Knowing these things, no great difficulty should be found in establishing the charges within the bounds of practical accuracy.

For the reason that arithmetical averages as obtained from available records gave few rational values for depreciation and repairs, such averages were given less weight in establishing the tabular amounts than the practical experience of contractors. In fact, the strongest evidence that these amounts are reasonably safe and accurate lies in the endorsement given them by experienced general contractors.

It may be recalled that a tentative draft of the schedule was submitted to members in the Weekly Bulletin of July 31. They were asked to criticize the amounts and offer suggestions. In accordance with the criticism received, which evinced considerable study upon the subject, some of the tabular amounts were changed. As it now stands the schedule represents the consensus of opinion of many contractors, and with the proper understanding of what the percentage amounts mean, it should offer a safe means of estimating rental charges.

WHAT THE VALUES MEAN.

The endless variation of job conditions, such as topography, ground formation and climate, indicate how great may be the error of any fixed equipment charge when applied to the exceptional job. But having figures which represent the mean of many projects, a starting point exists for ascertaining reasonable charges for the exceptional circumstances. Figures given in the standard schedule may be said to show equipment expense when machines are not required to operate continuously under either the worst or the best of operation strain. When no especially favorable or unfavorable circumstances attend a project, the tabular values probably give the expense within a permissible error.

To eliminate error as far as possible by permitting consideration and comparison of the individual items that make up equipment expense, the gross amounts are reduced to their component parts. Thus any item

of the expense which is known to be unusually high in specific cases may be adjusted in the schedule to obtain a more appropriate rental rate.

COMPONENT OF EXPENSE.

Seven items of equipment expense constitute the total rental charge and require consideration in estimating a lump sum contract or in determining fixed rate rentals. An average value for each of these items which represents the expense of a general contractor's outfit as a whole, have been approved by the executive board. The items referred to and their annual proportions of the equipment's initial cost are as follows:

SCHEDULE OF TYPICAL RENTAL CHARGE

Items of expense are expressed as per cents of original capital investment for equipment having a useful life of 6 years and a salvage value of 25% of the original cost.

	Per Cent
1. Average depreciation..................................	$12\frac{1}{2}$
2. Equivalent annual interest at $6\frac{1}{2}$%.............	4
3. Shop Repairs..	6
4. Field repairs...	4
5. Storage and incidentals...............................	$3\frac{1}{2}$
6. Insurance...	1
7. Taxes...	1
Total annual expense...................	32
Equivalent expense on basis of 8 months' working time per year..............................	48
Rental rate per month.................................	4

HOW TO OBTAIN PROPER PERCENTAGE

These percentages and those given in the detailed schedule were determined according to the following principles:

The economical life of a machine is considered to end when its value has depreciated to 25% of the original cost. The average annual depreciation then amounts to 75% of the initial cost divided by the number of years it may be expected to give service. The initial cost of a machine is represented by the cost of that machine delivered at the contractor's yard.

Interest should naturally be charged at the prevailing rate. This may be computed in three ways:

1. By charging the prevailing rate each year on the depreciated value of the machine.

2. By charging the prevailing rate each year on the average value of the machine during economical life. For example, when the salvage rate value is 25% the average value equals (100% by 25%)

divided by 2 = $62\frac{1}{2}\%$.

3. By finding the proportion which the average value is of the initial cost and charging this proportion of the prevailing rate each year. This proportion is called the equivalent annual interest and shows what interest rate on original cost will yield the same interest as the prevailing rate when applied to the depreciating value of the machine. This is the method used in the above schedule. The average value is $62\frac{1}{2}\%$ of the original; therefore the equivalent annual rate is $62\frac{1}{2}\%$ of the prevailing rate, or $62\frac{1}{2}\%$ of $6\frac{1}{2}\% = 4\%$.

Shop and field repairs are separated by reason of a previous recommendation of the committee on methods that field repairs be considered a part of the cost under cost plus contracts and shop repairs be borne by the contractor and covered by the fixed rate rental charge. This recommendation was made on the ground that an owner should not be made to pay the total cost, for example, of re-fluing a boiler which may have been burned out principally on another owner's work.

The other items of cost require no special explanation.

THREE TYPES OF CHARGES

Owners of equipment find occasion to establish rental rate as follows:

1. For a lump sum or unit price estimate.
2. To owners on cost plus work.
3. To others than client owners.

In these instances charges should be made as follows:

1. The rental charge or equipment expense for lump sum work includes all the items mentioned above.

2. The fixed rate to owners on cost plus work will include all but field repairs, if this item is paid as a cost of the work. To the amount thus determined may be added a service charge depending upon the policy of the contractor, i.e., whether the service of equipment is included in the profit fee or carried in the rental charge.

3. The charge to persons other than client owners includes all of the items of expense and an additional amount for profit or payment for the machine's earning power.

A further consideration in each of these cases is the rate for double shift work, where the percentages for depreciation and repairs should be doubled, or nearly so.

INDIVIDUAL JUDGMENT ESSENTIAL.

The committee desires to emphasize the fact that the values presented in the following table should not be considered absolute in determining a rental charge. A real danger presents itself in using any tabular percentage without investigating the conditions under which the

equipment is to work. To illustrate. If the values here given for a standard gage shovel outfit were applied to such an outfit engaged constantly in excavating hard rock, the probability is that the charges allowed would not cover more than half the expense. The frequent dobey shots and the dropping of heavy boulders into cars entails a higher rate of depreciation and repairs than is given in the schedule. On the other hand, if this shovel outfit were steadily engaged in digging sandy loam, the values given in the table would probably cause the equipment charge to contain a fair per cent of profit.

It is with the understanding that individual judgment and experience should adjust the tabular values to meet unusual conditions that this schedule is offered to contractors.

The component expenses incurred by the ownership and maintenance of construction plant are expressed in this table as percentages of the initial cost for individual items of equipment. They indicate the probable annual expense without profit under ordinary job conditions and should be included in any lump sum estimate or in determining time rate rental charges. The salvage value in all cases is considered to be 25% of the initial cost.

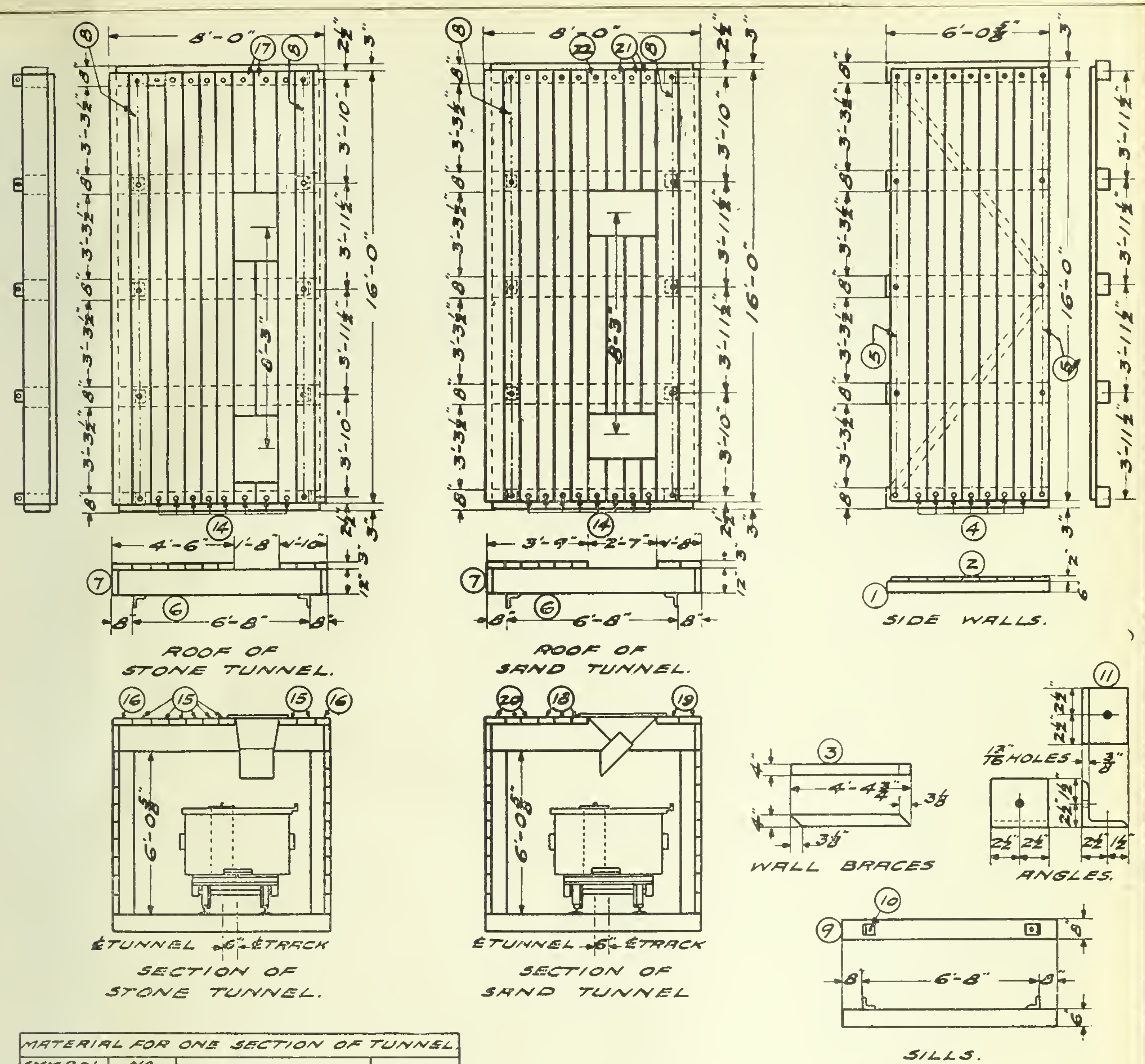
Total percentage amounts in the extreme right-hand column should be applied to the total cost of a machine including charges for transportation from the factory. This gives the total annual charge which for a lump sum contract covering a full season is the total equipment expense. For determining a monthly, weekly or daily rental rate the annual amount is divided by the number of such periods in the year during which construction work may be carried on.

Items of Equipment	Economical length of Life	Ann'l Depreciation	Ann'l Shop Repairs	Ann'l Field Repairs	Storage & Incidentals	Insurance	Taxes	Total Annual Chg.% of Initial Investm't
	Yrs.	%	%	%	%	%	%	%
Auto-crane	5	15	6	5	$3\frac{1}{2}$	1	1	$31\frac{1}{2}$
Auto-truck	3	25	20	20	$3\frac{1}{2}$	1	1	$70\frac{1}{2}$
Auto-trailer	5	15	6	5	$3\frac{1}{2}$	1	1	$31\frac{1}{2}$
Backfiller, power	4	$18\frac{3}{4}$	6	7	$3\frac{1}{2}$	1	1	$37\frac{1}{4}$
Ballast spreader	8	$9\frac{1}{2}$	6	4	$3\frac{1}{2}$	1	1	25
Boiler, upright	8	$9\frac{1}{2}$	20	5	$3\frac{1}{2}$	1	1	40
Boiler, locomotive	8	$9\frac{1}{2}$	15	5	$3\frac{1}{2}$	1	1	35
Bucket, clam shell	4	$18\frac{3}{4}$	15	6	$3\frac{1}{2}$	1	1	$45\frac{1}{4}$
Bucket, orange-peel	4	$18\frac{3}{4}$	25	6	$3\frac{1}{2}$	1	1	$55\frac{1}{4}$
Bucket, drag-line	4	$18\frac{3}{4}$	12	3	$3\frac{1}{2}$	1	1	$39\frac{1}{4}$
Cars, steel dump	6	$12\frac{1}{2}$	8	4	$3\frac{1}{2}$	1	1	30
Cars, wood dump	5	15	7	3	$3\frac{1}{2}$	1	1	$30\frac{1}{2}$
Cars, flat	8	$9\frac{1}{2}$	4	3	$3\frac{1}{2}$	1	1	22
Cars, hopper	5	15	8	3	$3\frac{1}{2}$	1	1	$31\frac{1}{2}$
Compressor, steam	7	$10\frac{3}{4}$	6	3	$3\frac{1}{2}$	1	1	$25\frac{1}{4}$
Compressor, gasoline	4	$18\frac{3}{4}$	6	7	$3\frac{1}{2}$	1	1	$37\frac{1}{4}$
Compressor, electric	6	$12\frac{1}{2}$	3	3	$3\frac{1}{2}$	1	1	24
Concrete chutes	2	$37\frac{1}{2}$	15	15	$3\frac{1}{2}$	1	1	73
Conveyor, belt	2	$37\frac{1}{2}$	7	6	$3\frac{1}{2}$	1	1	56
Conveyor, bucket	2	$37\frac{1}{2}$	10	6	$3\frac{1}{2}$	1	1	59
Crusher, rock	6	$12\frac{1}{2}$	5	3	$3\frac{1}{2}$	1	1	26
Derrick, wood	5	15	4	4	$3\frac{1}{2}$	1	1	$28\frac{1}{2}$
Derrick, steel	10	$7\frac{1}{2}$	4	3	$3\frac{1}{2}$	1	1	20
Dragline, steam	6	$12\frac{1}{2}$	9	8	$3\frac{1}{2}$	1	1	35
Dragline, gasoline	4	$18\frac{3}{4}$	10	10	$3\frac{1}{2}$	1	1	$44\frac{1}{4}$
Dragline, electric	8	$9\frac{1}{2}$	7	7	$3\frac{1}{2}$	1	1	29
Drill, tunnel carriage	5	15	8	8	$3\frac{1}{2}$	1	1	$36\frac{1}{2}$
Drill, traction.well,	6	$12\frac{1}{2}$	7	10	$3\frac{1}{2}$	1	1	35
Drill, jack hammer	4	$18\frac{3}{4}$	7	6	$3\frac{1}{2}$	1	1	$37\frac{1}{4}$
Drill, tripod	4	$18\frac{3}{4}$	7	10	$3\frac{1}{2}$	1	1	$41\frac{1}{4}$
Engine, gas	6	$12\frac{1}{2}$	8	8	$3\frac{1}{2}$	1	1	34
Engine, steam	10	$7\frac{1}{2}$	5	5	$3\frac{1}{2}$	1	1	23
Excavator, cableway	6	$12\frac{1}{2}$	4	12	$3\frac{1}{2}$	1	1	34
Excavator, Keystone	5	15	8	4	$3\frac{1}{2}$	1	1	$32\frac{1}{2}$
Excavator, trench	5	15	8	6	$3\frac{1}{2}$	1	1	$34\frac{1}{2}$
Forms, steel concrete	2	$37\frac{1}{2}$	20	20	$3\frac{1}{2}$	1	1	83
Graders, common road	4	$18\frac{3}{4}$	12	6	$3\frac{1}{2}$	1	1	$42\frac{1}{4}$
Graders, elevating	4	$18\frac{3}{4}$	15	7	$3\frac{1}{2}$	1	1	$46\frac{1}{2}$
Hoist, steam	10	$7\frac{1}{2}$	6	4	$3\frac{1}{2}$	1	1	23
Hoist, gasoline	6	$12\frac{1}{2}$	7	8	$3\frac{1}{2}$	1	1	33
Hoist, electric	8	$9\frac{1}{2}$	5	3	$3\frac{1}{2}$	1	1	23

Two pages of chart - page #1.

Items of Equipment	Economical length of Life	Ann'l depreciation	Ann'l shop repairs	Ann'l Field Repairs	Storage & Incidentals	Insurance	Taxes	Total Ann'l Chg.% of Initial Invest.
	Yrs.	%	%	%	%	%	%	%
Locomotive, Indus. Steam.........	9	8½	6	4	3½	1	1	24
Locomotive, Indus. Gas...........	4	18¾	13	10	3½	1	1	47¼
Locomotive, Indus. Batter........	4	18¾	15	4	3½	1	1	43¼
Locomotive, Standard gage.......	10	7½	6	4	3½	1	1	23
Locomotive crane, steam.........	8	9½	7	8	3½	1	1	30
Locomotive crane, elec..........	8	9½	6	4	3½	1	1	25
Mixer, steam....................	5	15	12	4	3½	1	1	36½
Mixer, gasoline.................	4	18¾	13	8	3½	1	1	45¼
Mixer, electric.................	6	12½	12	4	3½	1	1	34
Mixer, paving steam.............	5	15	13	4	3½	1	1	37½
Mixer, paving gas...............	3	25	16	9	3½	1	1	55½
Motors..........................	6	12½	6	4	3½	1	1	28
Pile driver, steam..............	8	9½	7	5	3½	1	1	27
Pile driver, track..............	10	7½	5	3	3½	1	1	21
Pile hammer, steam..............	7	10¾	7	3	3½	1	1	26¼
Pipe, galvanized................	3	25	5	6	3½	1	1	41½
Plows...........................	3	25	15	10	3½	1	1	55½
Pneumatic concrete machine,.....	4	18¾	20	8	3½	1	1	52¼
Pump, centrifugal...............	8	9½	6	4	3½	1	1	25
Pump, piston....................	6	12½	7	5	3½	1	1	30
Pump, pulsometer................	8	9½	2	4	3½	1	1	21
Pump, Emerson...................	8	9½	2	4	3½	1	1	21
Rails...........................	8	9½	5	3	3½	1	1	23
Riveter, air....................	5	15	8	4	3½	1	1	32½
Rock channeler..................	6	12½	7	8	3½	1	1	33
Roller, steam road..............	10	7½	5	3	3½	1	1	21
Saw rigs........................	4	18¾	10	15	3½	1	1	49¼
Scraper, wheel..................	3	25	8	4	3½	1	1	42½
Scraper, slip...................	1	75	25	10	3½	1	1	115½
Scraper, fresno.................	2	37½	25	15	3½	1	1	83
Shovel, steam...................	6	12½	7	6	3½	1	1	31
Shovel, gasoline................	4	18¾	9	7	3½	1	1	40¼
Shovel, electric................	7	10¾	6	5	3½	1	1	27¼
Switches, fabricated............	3	25	3	3	3½	1	1	36½
Tower, steel hoist..............	7	10¾	3	4	3½	1	1	23¼
Tractor, wheel gas..............	6	12½	9	5	3½	1	1	32
Tractor, caterpillar............	5	15	15	10	3½	1	1	45½
Wagons, dump....................	4	18¾	17	3	3½	1	1	44¼
Wagons, hauling.................	4	18¾	12	3	3½	1	1	39¼
Wagon loaders, power............	5	15	10	6	3½	1	[illegible]	36½

Two Pages of Chart - Page #3.



ROOF OF STONE TUNNEL.

ROOF OF SAND TUNNEL.

SIDE WALLS.

SECTION OF STONE TUNNEL.

SECTION OF SAND TUNNEL.

WALL BRACES

ANGLES.

SILLS.

MATERIAL FOR ONE SECTION OF TUNNEL.				
SYMBOL Nº	Nº REQ'D.	DESCRIPTION	LENGTH.	
1	10	STRUTS - 6"X8"	6'-0⅝"	FOR ALL TUNNELS
2	18	PLANKS - 2"X8"	16'-0"	
3	8	WALL BRACES - 4"X4"	4'-4¾"	
4	28	BOLTS - ⅜"	0'-9"	
5	20	BOLTS - ⅜"	0'-9½"	
6	5	BEAMS - 8"X12"	7'-8"	
7	2	PLANKS - 2"X12"	16'-0"	
8	10	BOLTS - ⅜"	1'-4½"	
9	5	SILLS - 6"X8"	8'-0"	
10	10	BOLTS - ⅜"	0'-7½"	
11	20	ANGLES - 4"X4"X⅜"	0'-5"	
12	15#	SPIKES	20 D	
13	10#	SPIKES	40 D	
14	16	BOLTS - ⅜"	1'-4"	
15	8	PLANKS - 3"X8"	16'-0"	STONE TUNNELS ONLY
16	2	PLANKS - 3"X6"	16'-0"	
17	2	PLANKS - 3"X10"	10'-10"	
18	3	PLANKS - 3"X8"	16'-0"	SAND TUNNELS ONLY
19	2	PLANKS - 3"X10"	16'-0"	
20	3	PLANKS - 3"X7"	16'-0"	
21	3	PLANKS - 3"X8"	12'-8"	
22	1	PLANK - 3"X7"	12'-8"	
ITEMS 17, 21 AND 22 CUT TO SUIT.				

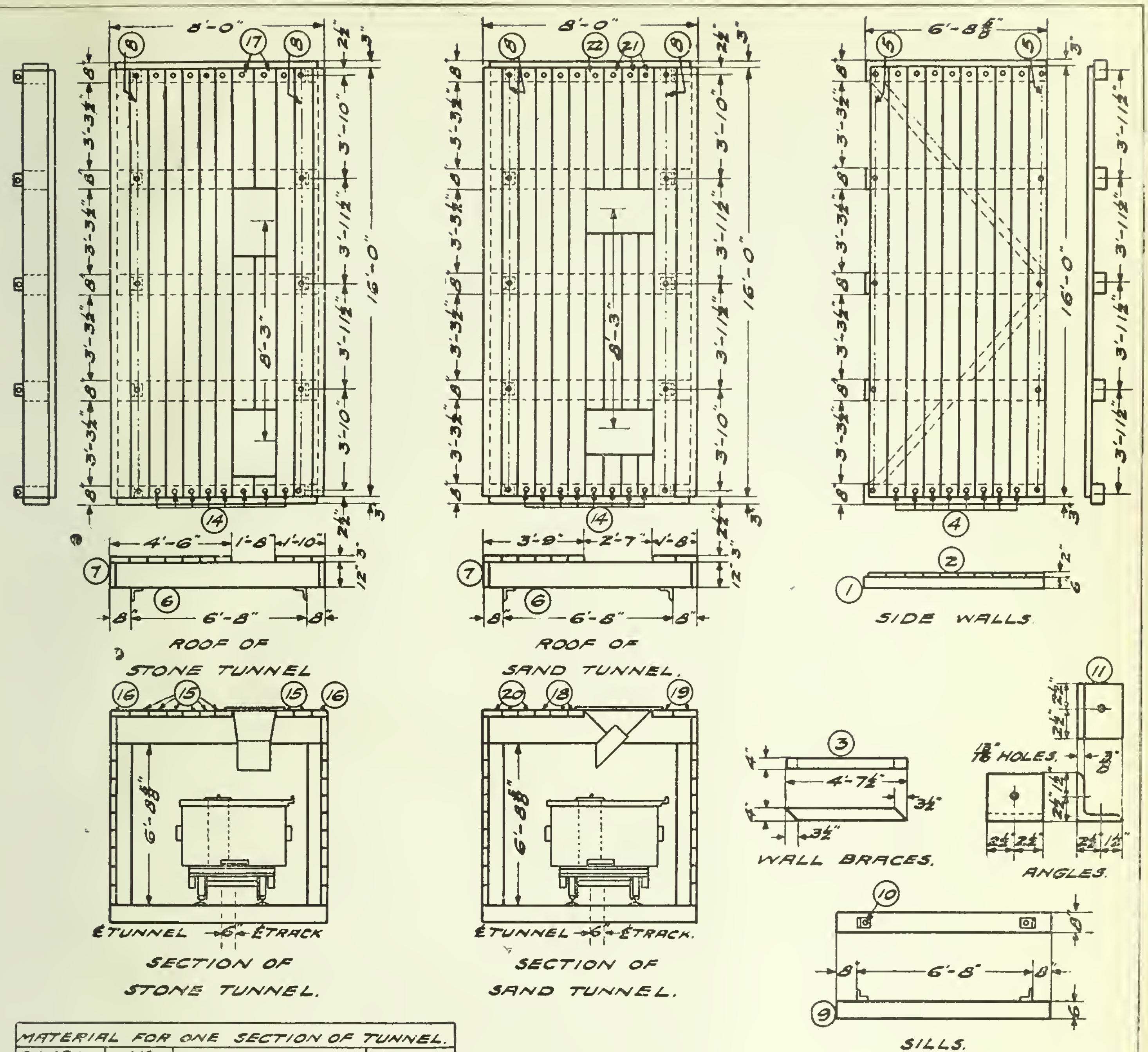
THIS TUNNEL IS DESIGNED WITHOUT REFERENCE TO LOCOMOTIVE HEIGHTS - AS LAKEWOOD DOES NOT RECOMMEND THAT LOCOMOTIVES BE RUN THROUGH THE TUNNEL.

FOR GENERAL DATA SEE DRW'G #108.
FOR DETAIL OF TUNNEL TRAP SEE DRW'G. #111.
FOR DESIGN OF TUNNEL FOR 37 CU.FT. BATCHES SEE DRW'G. #110

THE LAKEWOOD ENGINEERING CO.
CLEVELAND OHIO.

DESIGN OF TUNNEL.
FOR
25 OR 29 CU.FT. BATCHES.

JULY 6-1920.



MATERIAL FOR ONE SECTION OF TUNNEL.				
SYMBOL Nº	Nº REQ'D.	DESCRIPTION	LENGTH	
1	10	STRUTS-6"X8"	6'-8 5/8"	FOR ALL TUNNELS
2	20	PLANKS-2"X8"	16'-0"	
3	8	WALL BRACES-4"X4"	4'-7½"	
4	32	BOLTS-3/8"	0'-9"	
5	20	BOLTS-3/4"	0'-9½"	
6	5	BEAMS-8"X12"	7'-8"	
7	2	PLANKS-2"X12"	16'-0"	
8	10	BOLTS-3/4"	1'-4½"	
9	5	SILLS-6"X8"	8'-0"	
10	10	BOLTS-3/4"	0'-7½"	
11	20	ANGLES-4"X4"X3/8"	0'-5"	
12	15#	SPIKES	20 D	
13	10#	SPIKES	40 D	
14	16	BOLTS-3/8"	1'-4"	
15	8	PLANKS-3"X8"	16'-0"	STONE TUNNELS ONLY
16	2	PLANKS-3"X6"	16'-0"	
17	2	PLANKS-3"X10"	10'-10"	
18	3	PLANKS-3"X8"	16'-0"	SAND TUNNELS ONLY
19	2	PLANKS-3"X10"	16'-0"	
20	3	PLANKS-3"X7"	16'-0"	
21	3	PLANKS-3"X8"	12'-8"	
22	1	PLANK-3"X7"	12'-8"	
ITEMS 17, 21 AND 22 CUT TO SUIT.				

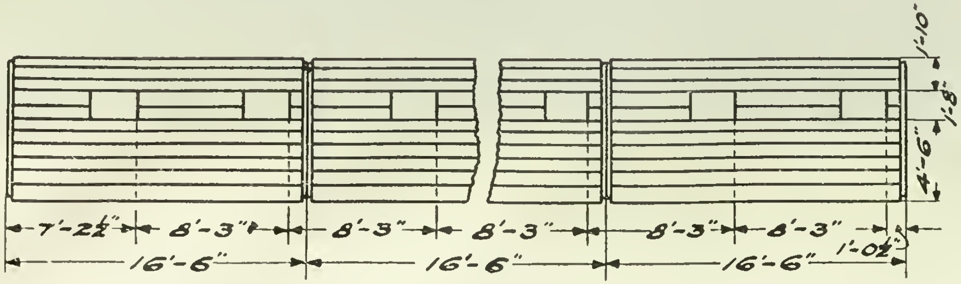
THIS TUNNEL IS DESIGNED WITHOUT REFERENCE TO LOCOMOTIVE HEIGHTS — AS LAKEWOOD DOES NOT RECOMMEND THAT LOCOMOTIVES BE RUN THROUGH THE TUNNEL.

FOR GENERAL DATA SEE DRWG. #108.
FOR DETAIL OF TUNNEL TRAP SEE DRWG. #111.
FOR DESIGN OF TUNNEL FOR 25 OR 29 CU.FT. BATCHES SEE DRG. #109.

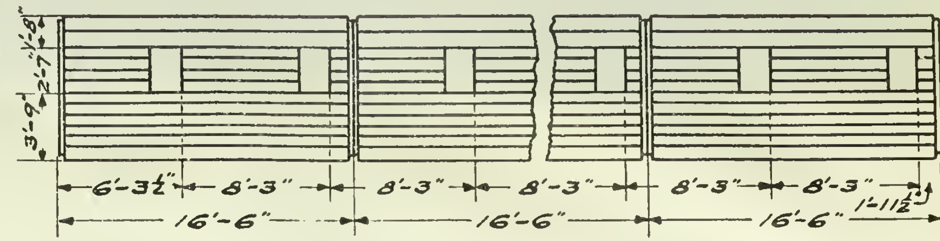
THE LAKEWOOD ENGINEERING CO.
CLEVELAND OHIO.

DESIGN OF TUNNEL
FOR
37 CU.FT. BATCHES.

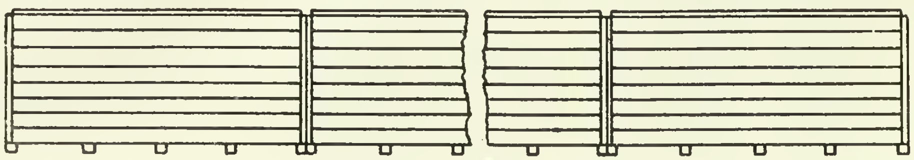
JULY 7-1920.



PLAN OF STONE TUNNEL.



PLAN OF SAND TUNNEL.



ELEVATION OF BOTH STONE AND SAND TUNNELS.

THE LENGTH OF TUNNEL REQUIRED IS DETERMINED BY THE LENGTH OF AVERAGE TRAIN TO BE UNLOADED PER DAY AND BY THE REACH OF THE BOOM ON THE CRANE.

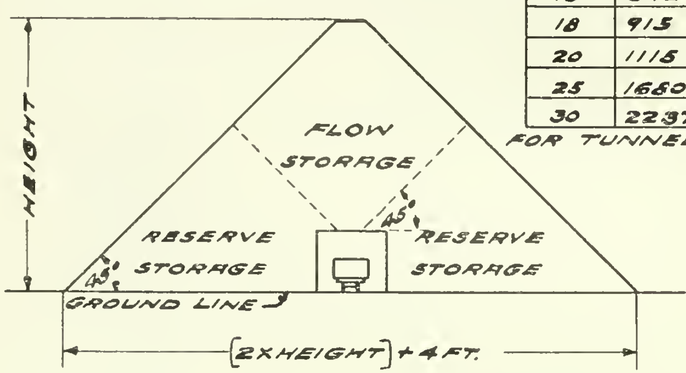
CAPACITIES PER 100 FEET OF TUNNEL.

HEIGHT FEET	RESERVE CU. YDS.	FLOW CU. YDS.	TOTAL CU. YDS.
15	642	206	848
18	915	344	1259
20	1115	455	1570
25	1680	798	2478
30	2237	1233	3470

FOR TUNNEL ABOVE GROUND.

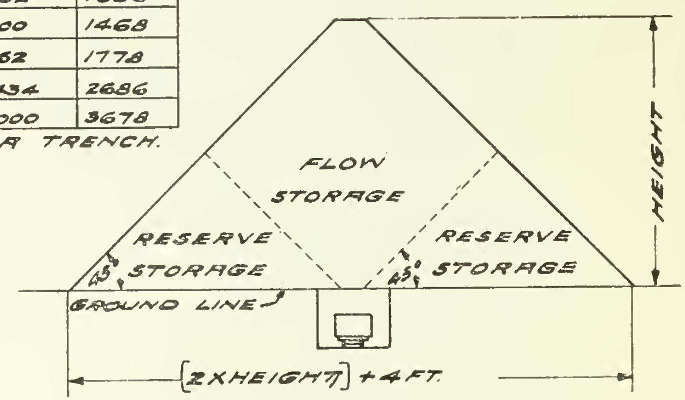
HEIGHT FEET	RESERVE CU. YDS.	FLOW CU. YDS.	TOTAL CU. YDS.
15	474	582	1056
18	668	800	1468
20	816	962	1778
25	1252	1434	2686
30	1678	2000	3678

FOR TUNNEL IN A TRENCH.



THE ABOVE TABLES CLEARLY INDICATE THE ADVISABILITY OF LOWERING THE TUNNEL INTO THE GROUND AS FAR AS POSSIBLE.

PROVISION MUST BE MADE TO DRAIN THE TUNNEL OF SURFACE WATER.



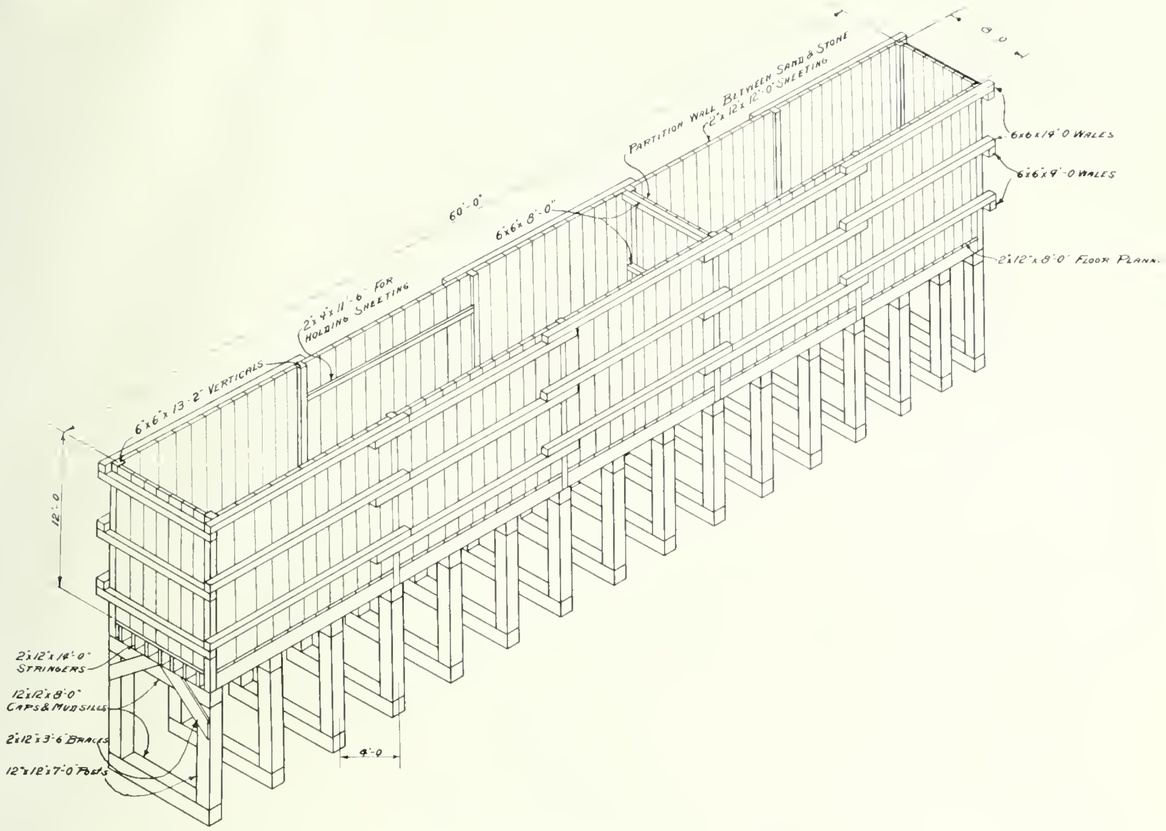
THE LAKEWOOD ENGINEERING CO.
CLEVELAND OHIO

LAKEWOOD TUNNEL—GENERAL DATA.

JULY 6-1920

FOR DETAILS OF TUNNEL TRAP SEE DRWG. #111
FOR DETAILS OF TUNNEL CONSTRUCTION SEE DRWGS. #109 AND #110.

DATA SHEET #108



200 Cubic Yard Storage Bins

For contractors who desire to build their own bins this design is suggested by the Lakewood Engineering Company.

The sketch, with the bill of material, gives practically all necessary information. (For bill of material see reverse side.)

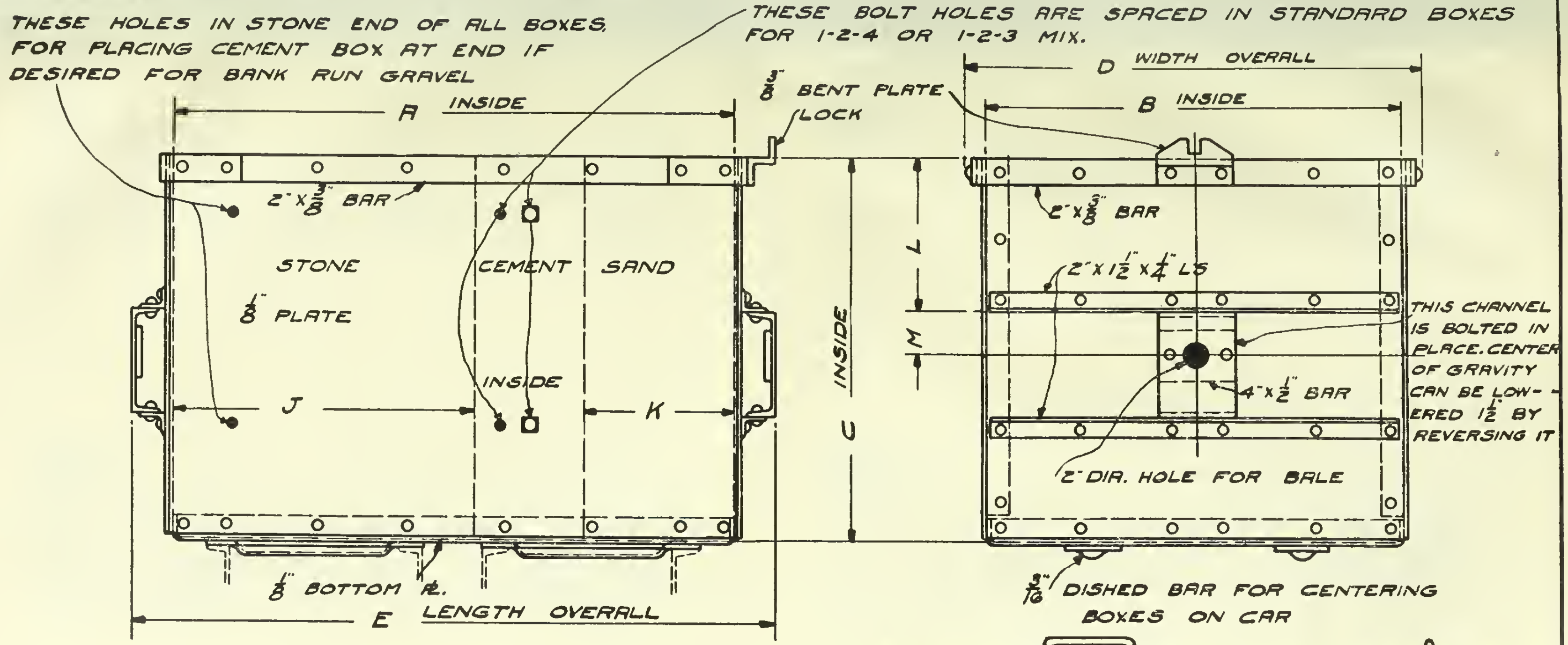
Place the partition wall to give proper ratio between sand and stone for various mixes. Place 1-inch tie rods in each system of 6″ x 6″ waling pieces 6′ 0″ apart horizontally. Waling pieces are bolted to 6″ x 6″ verticals and to each other with six $\frac{5}{8}$″ x 13$\frac{1}{2}$″ bolts at each joint. Place Lakewood tunnel traps at proper intervals at bottom. Use few nails in the flooring. Hold vertical sheeting in place by means of 2″ x 4″ on inside bolted through to 6″ x 6″ wales on outside.

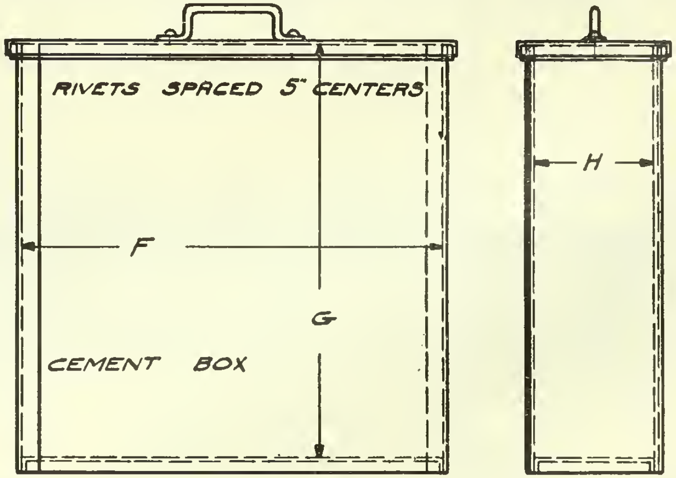
The Lakewood Engineering Company
Cleveland, U. S. A.

Bill of Material

Description	Dimension	Req'd.	B. F't
Caps and Mudsills	12"x12"x8'–0"	32	3072
Posts	12"x12"x7'–0"	32	2688
Stringers	2"x12"x14'–0"	40	1120
Side Wales	6"x6"x14'–0"	30	1260
End Wales	6"x6"x9'–0"	6	162
Partition Wales	6"x6"x8'–0"	3	72
Flooring	2"x12"x8'–0"	60	960
Sheeting	2"x12"x12'–0"	135	3240
Verticals	6"x6"x13'–2"	12	500
Sheeting Holder	2"x4"x11'–6"	24	192
Brace	2"x12"x3'–6"	32	224
Bolts	5/8"–x13 1/2"	216	310 lb.
Bolts (For Sheet H.)	1/2"–x10 1/2"	72	
Tie Rods	1"x9'–6"	27	702 lb.
Nails	20D		50 lb.
Nails	10D		25 lb.

SUBJECT: DIMENSION SKETCH OF BATCH BOXES WITH CEMENT COMPARTMENT — DATA SHEET No. 77





CAP'Y	A	B	C	D	E	F	G	H	WEIGHT OF BATCH BOX	WEIGHT OF CEMENT BOX
25	$44\frac{5}{8}$"	$32\frac{5}{8}$"	$30\frac{1}{8}$"	35"	$49\frac{7}{8}$"	$31\frac{3}{4}$"	$30\frac{3}{8}$"	$8\frac{3}{4}$"	341#	62#
29	$44\frac{5}{8}$"	$32\frac{5}{8}$"	$36\frac{1}{8}$"	35"	$49\frac{7}{8}$"	$31\frac{3}{4}$"	$36\frac{7}{8}$"	$8\frac{3}{4}$"	376#	72#
37	$44\frac{5}{8}$"	$32\frac{5}{8}$"	$44\frac{1}{8}$"	35"	$49\frac{7}{8}$"	$31\frac{3}{4}$"	$44\frac{1}{8}$"	$8\frac{3}{4}$"	421#	83#

SEE DATA #78 FOR CHART OF MIXES AND CAPACITIES

CAP'Y CU. FT	MIX	J	K	L	M
25	3 BAGS 1-2-4	$23\frac{3}{4}$"	12"	12"	$4\frac{3}{4}$"
29	4 BAGS 1-2-4	$23\frac{3}{4}$"	12"	$18\frac{1}{2}$"	$3\frac{1}{4}$"
37	5 BAGS 1-2-4	$23\frac{3}{4}$"	12"		$3\frac{1}{4}$"

CAP'Y CU. FT	MIX	J	K	L	M
29	5- BAGS-1-$1\frac{1}{2}$-3	$23\frac{3}{4}$"	12	$18\frac{1}{2}$"	$3\frac{1}{4}$"
37	6- BAGS-1-$1\frac{1}{2}$-3	$23\frac{3}{4}$"	12	$23\frac{5}{8}$"	$4\frac{3}{4}$"

CAP'Y CU. FT	MIX	J	K	L	M
25	4 BAGS 1-2-3	$21\frac{1}{2}$"	$14\frac{1}{4}$"	12"	$3\frac{1}{4}$"
29	4 BAGS 1-2-3	$21\frac{1}{2}$"	$14\frac{1}{4}$"	$18\frac{1}{2}$"	$4\frac{3}{4}$"
37	6 BAGS 1-2-3	$21\frac{1}{2}$"	$14\frac{1}{4}$"	$23\frac{5}{8}$"	$3\frac{1}{4}$"

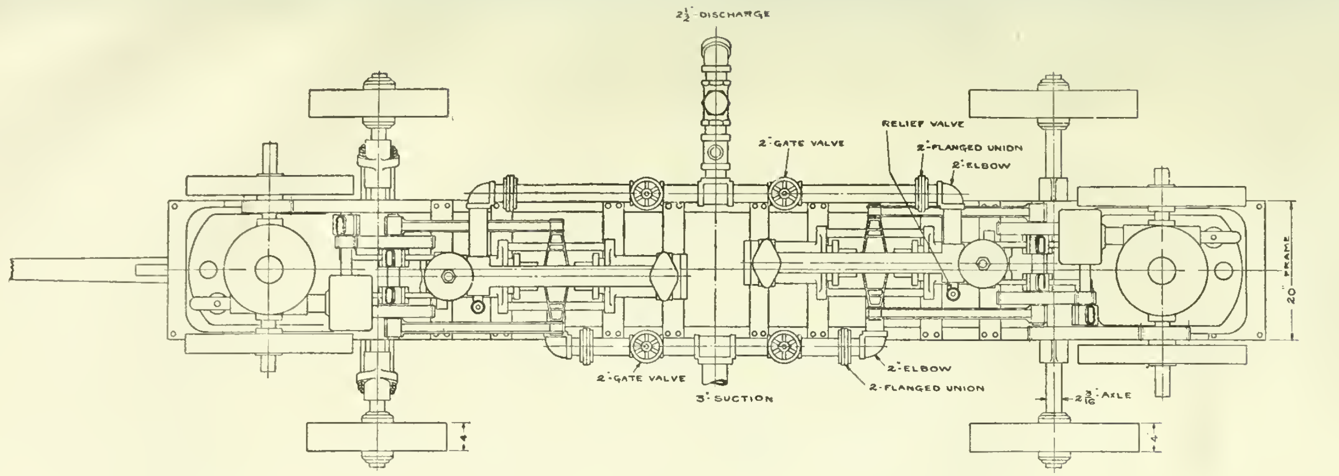
CAP'Y CU. FT	MIX	J	K	L	M
29	4- BAGS-1-2-$3\frac{1}{2}$	$23\frac{3}{4}$"	12"	$18\frac{1}{2}$"	$3\frac{1}{4}$"
37	5- BAGS-1-2-$3\frac{1}{2}$	$21\frac{1}{2}$"	$14\frac{1}{4}$"	$23\frac{5}{8}$"	$4\frac{3}{4}$"

	CAP'Y CU. FT	MIX	J	K	L	M
*	25	4 BAGS-1-$1\frac{1}{2}$-$3\frac{1}{2}$	$23\frac{3}{4}$"	12"	12"	$3\frac{1}{4}$"
	29	4 BAGS-1-$1\frac{1}{2}$-$3\frac{1}{2}$	$23\frac{3}{4}$"	12"	$18\frac{1}{2}$"	$4\frac{3}{4}$"
*	37	6 BAGS-1-$1\frac{1}{2}$-$3\frac{1}{2}$	$23\frac{3}{4}$"	12"	$23\frac{5}{8}$"	$3\frac{1}{4}$"

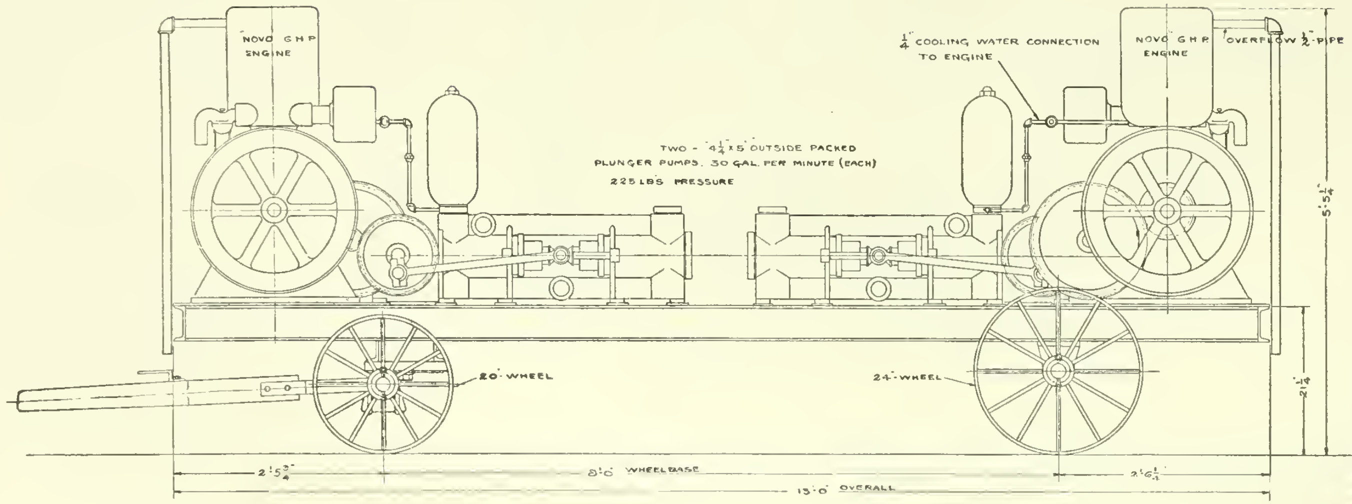
CAP'Y CU. FT	WATER LEVEL CAPACITIES						
	CEMENT BOX	OUTSIDE CEM. BOX	WITHOUT CEM. BOX	STONE 1-2-3	SAND 1-2-3	STONE 1-2-4	SAND 1-2-4
25	4.88	20.3	25.4	12.2	8.1	13.52	6.76
29	5.92	24.38	30.4	14.63	9.75	16.26	8.13
37	7.09	29.78	37.2	17.9	11.9	19.86	9.93

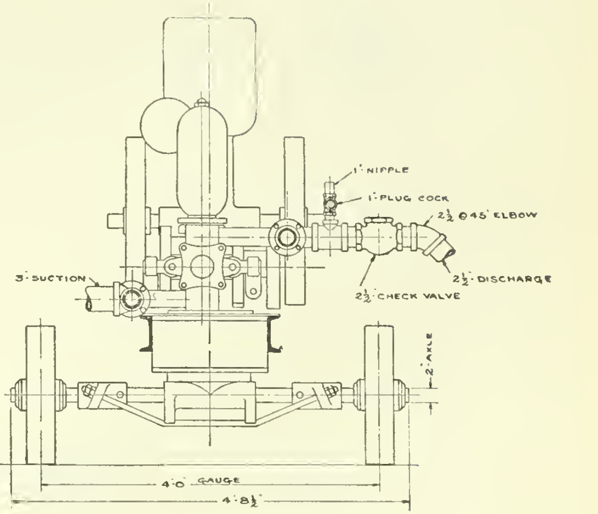
* THE STONE COMPARTMENTS FOR THESE MIXES ARE SLIGHTLY UNDER CAPACITY, THEY WOULD HAVE TO BE HEAPED OR EXTRA HOLES PLACED IN BOX TO SUIT

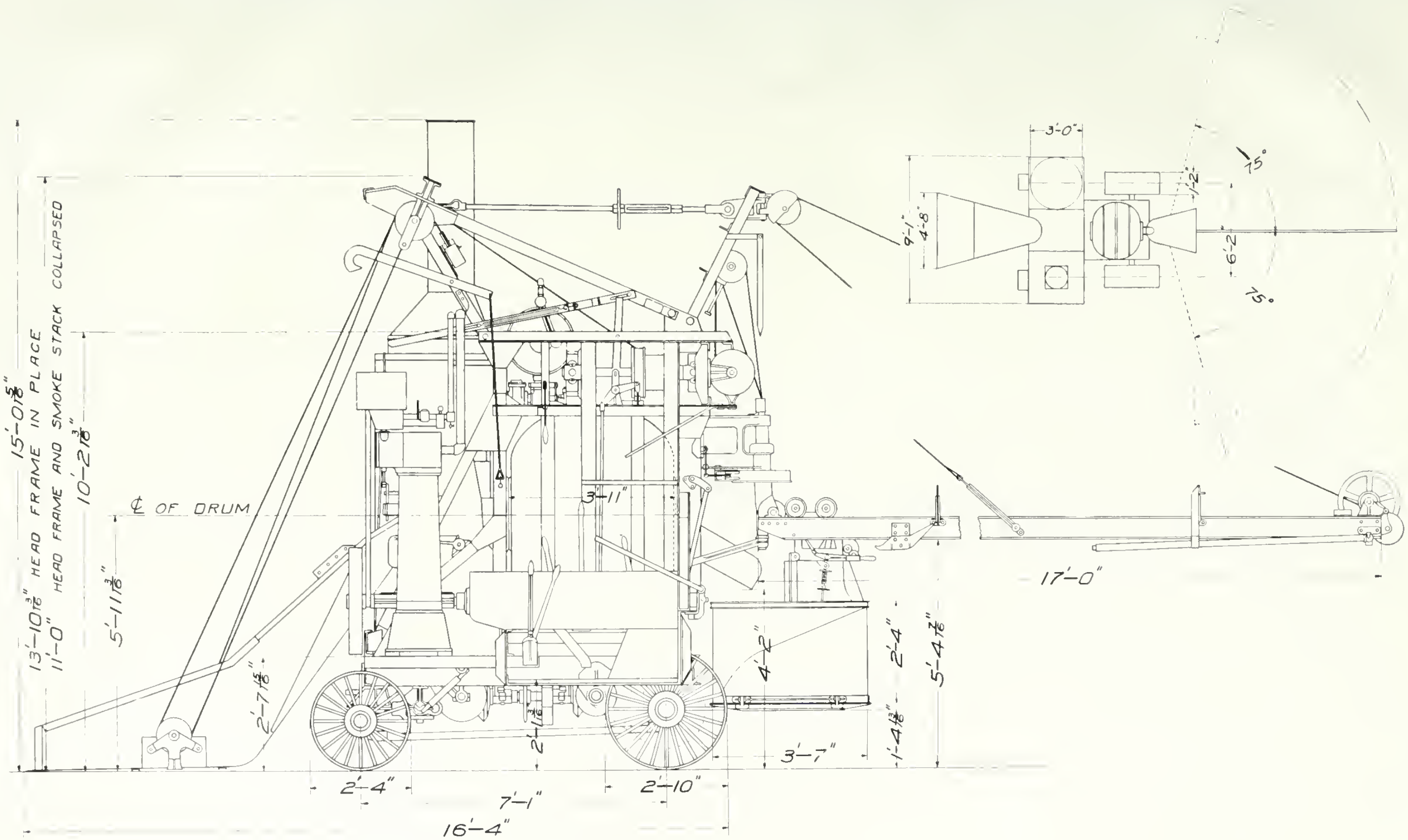
SEE DATA #77 FOR OUTLINE DRAWING OF BOXES



	FITTINGS RECOMMENDED FOR TWO MILE PIPE LINE
132	2"x1" MALL IRON TEES (SPACED 80 FT. APART)
132	1" PIPE PLUGS
7	2" EXPANSION JOINTS (EVERY 1800 FT.)
11	2" IRON BODY STOP COCKS (EVERY 1000 FT.
24	1" GARDEN VALVES (PER MIXER)
1	75 FT SECTION OF HOSE FOR MIXER SUPPLY
2	50 FT SECTIONS OF HOSE FOR CURING CONCRETE
1	1" PRESSURE VALVE TO BE LOCATED BACK OF MIXER - VALVE SET FOR PRESSURE DESIRED FOR MIXER, OVERFLOW WATER TO BE UTILIZED FOR CURING CONCRETE 25 TO 50 LB VALVE RECOMMENDED



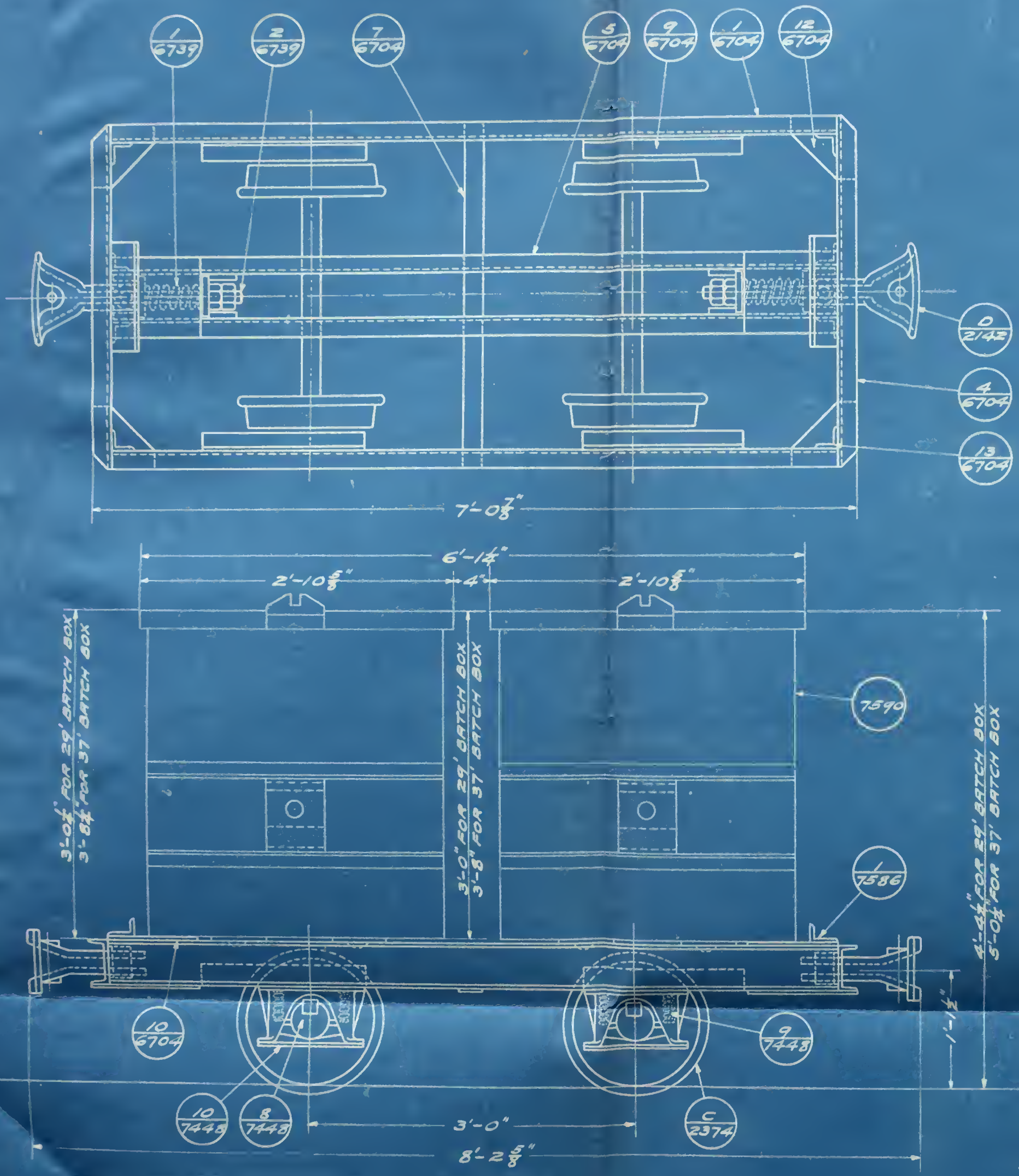


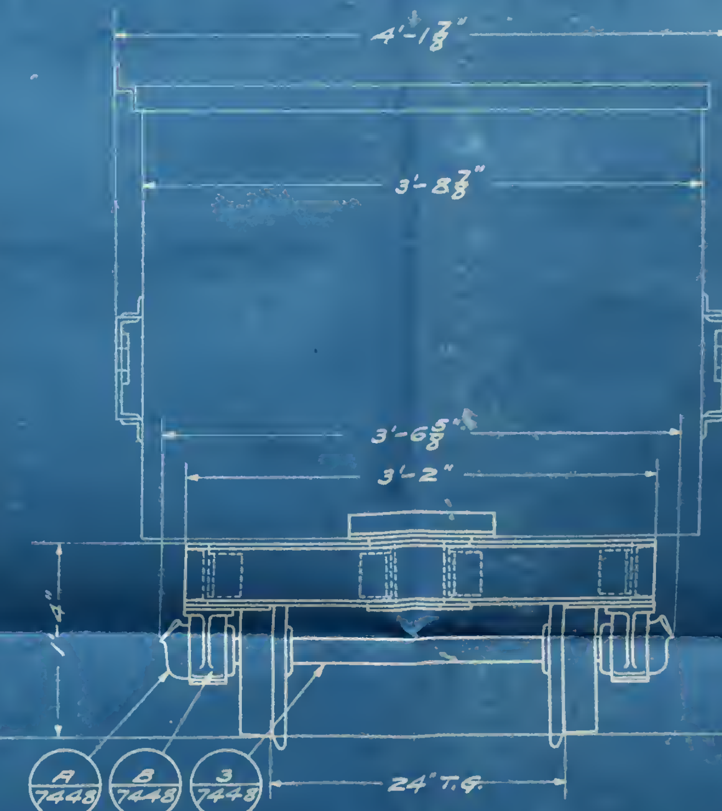


14-E Lakewood Milwaukee Paving Mixer

Lakewood Engineering Co. Cleveland, U. S. A.

Feb. 1921





SYMBOL		DESCRIPTION.
2374	C	14" DIA. CAST IRON CHILLED TREAD WHEEL
7448	3	2½" DIA. AXLE-.45 TO .55 CARBON-HEAT TREATED
7448	B	PEDESTAL-MALLEABLE IRON
7448	A	BEARING BOX
7448	10	1½"x¼" BAR
7448	8	HYATT ROLLER BEARING No 19425
6704	1	SIDE SILL-5"-6½ LB. CHANNEL
6704	4	END SILL-5"-6½ LB. CHANNEL
6704	5	CENTER SILL-5"-6½ LB. CHANNEL
6704	7	2"x¼" BAR
6704	9	2½"x2"x5/16" ANGLE
6704	10	8½"x¼" PLATE
6704	12	7"x¼" GUSSET PLATE
6704	13	2½"x2½"x¼" CLIP ANGLE
2142	D	DRAWHEAD-CAST STEEL
6739	1	SPRING-5/8" WIRE-2 3/4" O.D.-6½" F.H.
6739	2	1½" DIA. ROD
7586	1	3"x2"x¼" GUIDE ANGLE
7448	9	SPRING-9/16" WIRE-2½" O.D.-4" F.H.
7590		BATCH BOXES

CAR TO TAKE 18'-0" MINIMUM RAD. CURVE.

THE LAKEWOOD ENGINEERING CO.
Cleveland Ohio.

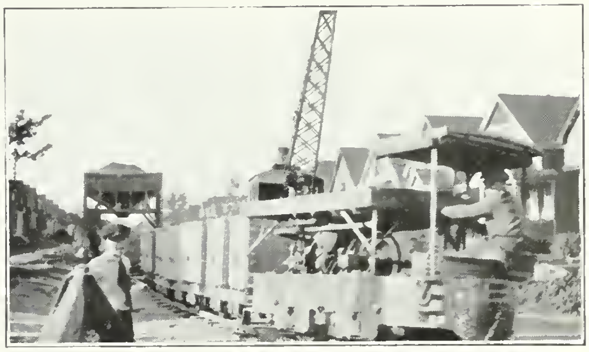
HEAVY TYPE BATCH BOX CAR-8200# CAPY.

FOR CARRYING TWO 29 OR TWO 37 CU.FT. BATCH BOXES.

NOVEMBER-1920.

Method for Direct Charging of Paving Mixer as Applied to City Street Construction

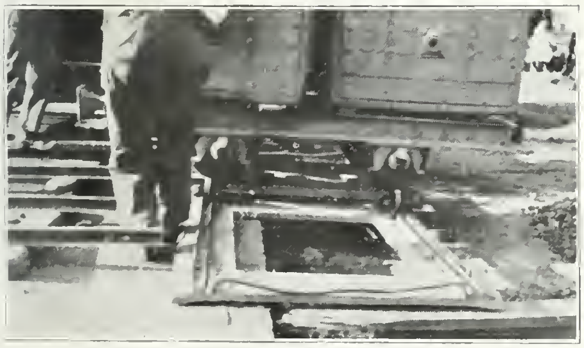
Sand and Stone are hauled to street intersections and handled into small portable bin with clamshell bucket. Bucket elevator or belt conveyor may also be used.



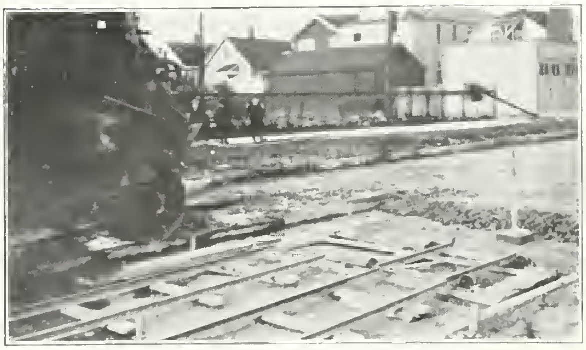
Each box is loaded from the bin with the exact amount of sand and stone for one batch for the paving mixer. Cement is placed in separate compartment. Two boxes are carried on each car. The train is pulled by a small gasoline locomotive.

Double track is laid on subgrade to mixer. Loaded batch boxes are hauled to mixer on inside track. Batch transfer uses weight of descending skip of paver to raise box from car. Box is swung over skip and dumped. Empty box is swung back and lowered onto car as skip is raised to discharge materials into drum.

Car and empty batch boxes are pushed onto "transfer track" and moved over to outside track.



The "transfer track" is made up of two short pieces of rail carried at the proper gauge on angles. Four rollers on these angles, run in channels, and allow the transfer to be easily moved from one track to the other.



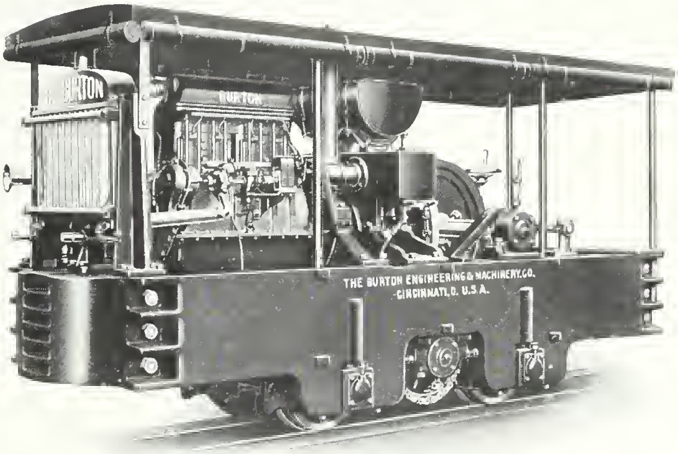
The "track transfer" is mounted on a wood frame, which can be picked up and moved as the concreting advances.

The Lakewood Engineering Co., Cleveland, Ohio, U. S. A.

Specification Sheet No. P. I.
The Lakewood Engineering Co.
Cleveland, U. S. A.

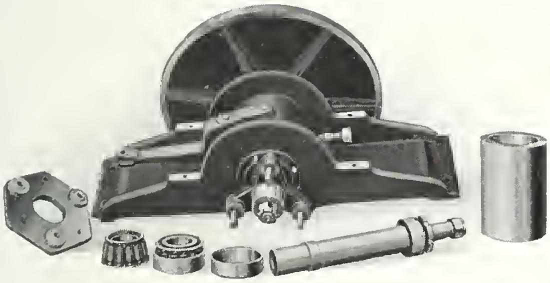
The Lakewood-Burton Locomotive

3½ and 6 Ton



THE most satisfactory motive power for narrow gauge railway haulage in every industry, in highway and general building construction, quarries, plantations, logging, brick and clay plants, sand and gravel pits, and industrial plants of every description.

The Burton Locomotive has been developed to its present perfection through many years of active service in these various fields of usefulness. It combines simplicity of construction, flexibility of operation, and economy of performance.



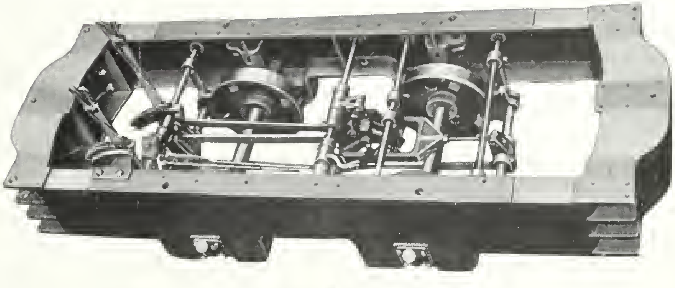
Friction Disc Assembly

Briefly, it consists of a power plant mounted on a rigid cast frame, carried on four flanged wheels set to a short wheelbase so that sharp curves may be easily negotiated.

Power is transmitted from the engine to the track wheels by means of a friction disc and roller chains, eliminating all spur and bevelled gears, friction clutches, and other complicated parts. This system of transmission enables the Burton Locomotive to operate with load in either direction at equal speeds and with equal efficiency. Operating speeds range from 2½ to 10 miles per hour.

Magneto ignition, radiator cooling system, fuel tanks with ample capacity for a full day's run, sand box, link and pin couplers adjustable to suit various heights of cars, are other features.

Brakes applied to all four wheels, controlled by a lever at the operator's

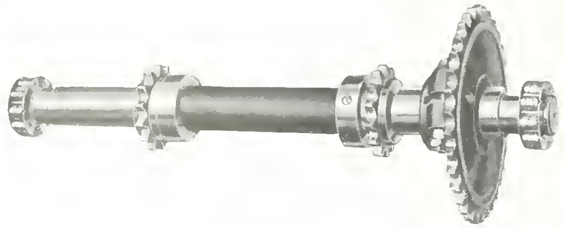


Frame Assembly

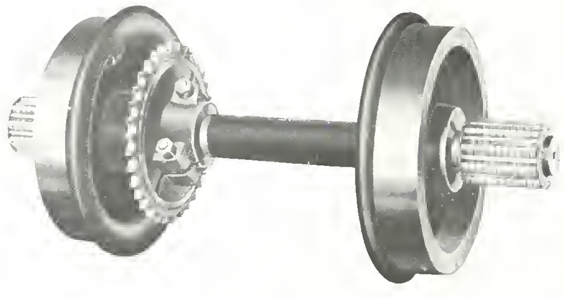
hand, have sufficient power to lock all wheels instantly in case of emergency.

A winding drum to carry steel cable is furnished when desired, for the purpose of snubbing cars, or for assisting in hauling up heavy inclines.

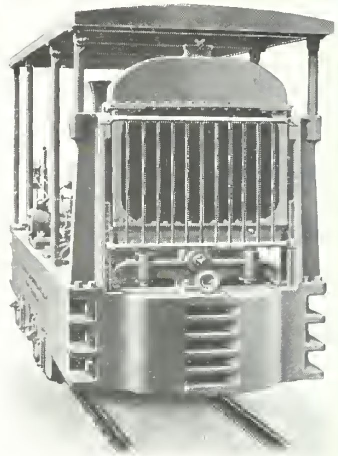
Track gauge is optional. Can be furnished in gauges of 18, 24, 30, 36, 42 and $56\frac{1}{2}$ in.



Jack Shaft Assembly



Axle Assembly



Front View

SPECIFICATIONS

Size	$3\frac{1}{2}$ Ton.	6 Ton.
Size of Motor	4 Cyl., $3\frac{1}{2}$ x 5.	4 Cyl., $4\frac{1}{2}$ x 6.
Horse Power:	23 at 1000 R.P.M.	46 at 1000 R.P.M.
Ignition:	Bosch High Tension Magneto.	Bosch High Tension Magneto.
Fuel:	Gasoline.	Gasoline.
Starting and Lighting:	Two Unit single wire system.	Two Unit single wire system.
Electrical Equipment (Extra)	Adjustable search lights, front and rear, Klaxon Horn.	Adjustable search lights, front and rear, Klaxon Horn.
Wheels:	Steel, pressed and keyed on axles; 18″ diam.	Steel, pressed and keyed on axles; 18″ diam.
Axles:	$3\frac{1}{4}$″ diam. high carbon steel, carried on Hyatt Bearings, supported by Spring Pedestals.	$3\frac{1}{2}$″ diam. high carbon steel, heat treated, carried on Hyatt Bearings, supported by Spring Pedestals.
Drive:	Friction disc drive by chains to jack shaft and from jack shaft by chains to both axles.	Friction disc drive by chains to jack shaft and from jack shaft by chains to both axles.
Friction Disc:	Cast Iron, 23″ diam.	Cast Iron 30″ diam.
Spur Friction:	Tarred Fibre, 22″ diam. Shaft carried on Hyatt Heavy Duty Bearings.	Tarred Fibre, $28\frac{1}{2}$″ diam. Shaft carried on Hyatt Heavy Duty Bearings.
Drive Chains:	Steel Roller, $\frac{3}{4}$″ Roller, $1\frac{1}{2}$″ Pitch.	Steel Roller, 1″ Roller, $1\frac{3}{4}$″ Pitch.
Wheel Base:	39″.	$48\frac{1}{2}$″.
Draw Bar Pull at 5 Miles per hour:	1400 lbs.	2400 lbs.
Track Gauge:	Optional 18 to $56\frac{1}{2}$″.	Optional, 18 to $56\frac{1}{2}$″.
Length:	10′ 5″.	12′ 5″.
Height:	Regular with cab 6′ 2″, without cab 4′ 9″.	Regular 6′ $3\frac{1}{2}$″, Special Construction 5′ 3″.
Width:	24″ Gauge, 49″	24″ Gauge, $55\frac{1}{2}$″.
Weight:	7000 lbs.	12000 lbs.
Brakes:	On all four wheels.	On all four wheels.
Cab:	Metal with side curtains. Extra for all-metal hood.	Metal with side curtains, Extra for all-metal hood.
Gasoline Capacity:	20 Gallons.	20 Gallons.
Gasoline Consumption:	Average conditions, 5 gal. in 10 hrs.	Average conditions, 9 gal. in 10 hours.

Instructions for Using The Lakewood Subgrader

The Lakewood Engineering Company
Cleveland U. S. A.

October 1920

Be Sure You Understand Instructions Fully Before Using Subgrader

The purpose of the Subgrader is to finish the subgrade after the rough grading has been completed.

The use of the Subgrader is practical only where materials are not hauled over the finished subgrade.

The Subgrader consists of cross-timbers on the under side of which is a series of steel blades bolted to angles. The arrangement of the angles to which these blades are attached for the various widths is shown by the diagram on the opposite page.

How the Subgrader is Shipped

The Subgrader is shipped with the angles, which carry the blades, in place.

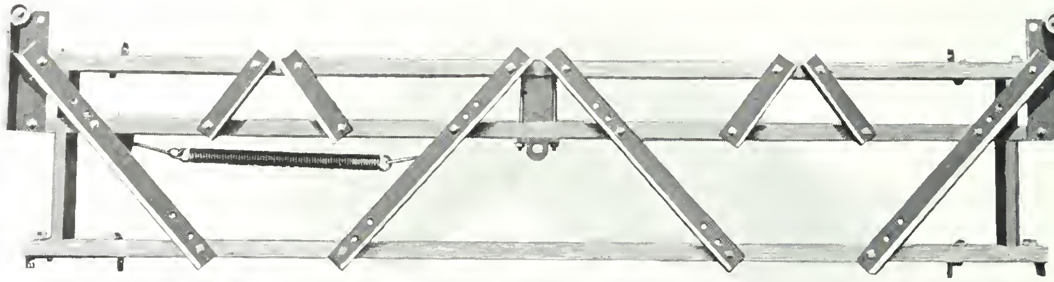
The following items are shipped separately:

One pulling cable, two hooks, thimble in bight.

One turntable foot and stem.

Four wheels with a grease cup screwed in each.

Blade angles—which with those shipped bolted to the frame of subgrader make up the full number for the 22-ft. subgrader, or a total of 6 long and 6 short angles.



The frame is shipped with the necessary blade angles bolted in position, and the compensating spring for the turntable in place. Upon receipt of the machine, the blades are bolted to the angles, the turntable assembled and put on, and wheels, axles, quadrants and levers attached to each end as shown in the other photographs.

One set of angles and two sets of cutting blades for the maximum width machine, (for a road 22-feet wide) are furnished with each Subgrader. This makes it possible to change the width of the machine by obtaining only the necessary cross-timbers. As there are always two sets of blades available, one can be sharpened while the other is in use.

The machine is mounted on rollers and travels on the forms set on both sides of the road to contain the road material or as a mold for the concrete. The axles for the rollers are made with an eccentric bend, so that by slightly rotating the axles the rollers are either lowered or raised in relation to the balance of the machine. Varying depths of cut are so provided.

The adjustment is made by levers held in position by pins set in holes on a quadrant.

Bolts and washers for fastening extra angles to frame. (2 bolts and 2 washers for each extra short angle, and 3 bolts and 3 washers for each long angle).

One turntable lever, with bolts inserted.

Four bundles containing 3 short blades each, with bolts inserted for fastening blades to angles.

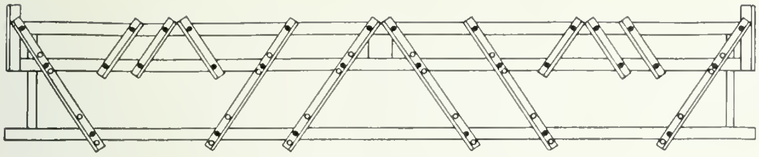
Six bundles, each containing 2 long blades with bolts inserted for fastening to angles.

One bundle, containing both end assemblies of quadrants, levers, and axles, complete, with pins wired in place.

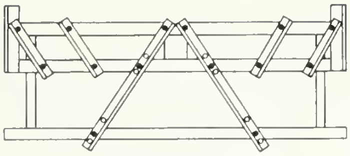
One assembly of links and levers for operating turntable, with all bolts in place.

Receiving the Machine

Upon receipt of the machine, the shipment should be checked to see that all the items as



22 FT.



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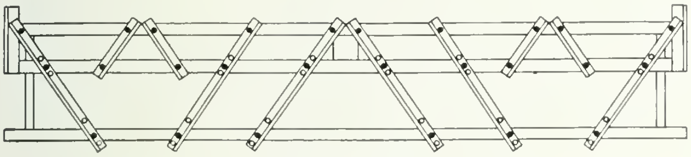

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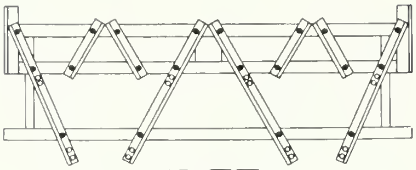
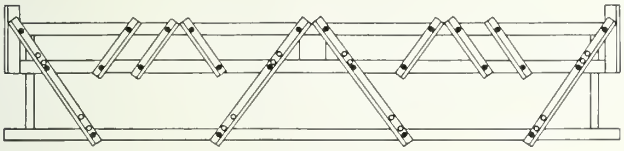
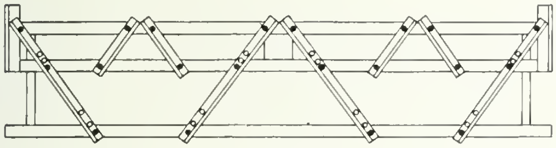


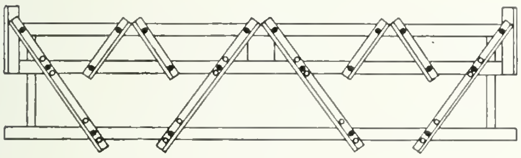
12 FT.



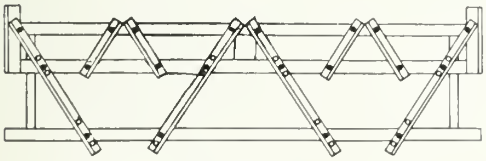
18 FT.



16 FT.



15 FT.



14 FT.

Diagram of Arrangement of Blade Angles *for* Various Widths of Subgraders

Blade angles and two complete sets of blades for the 22-ft. machine are furnished with each subgrader, regardless of width.

The angles required for the particular width of machine ordered are shipped bolted in place on the frame. The extra angles not required by such width are shipped separately as are all the blades.

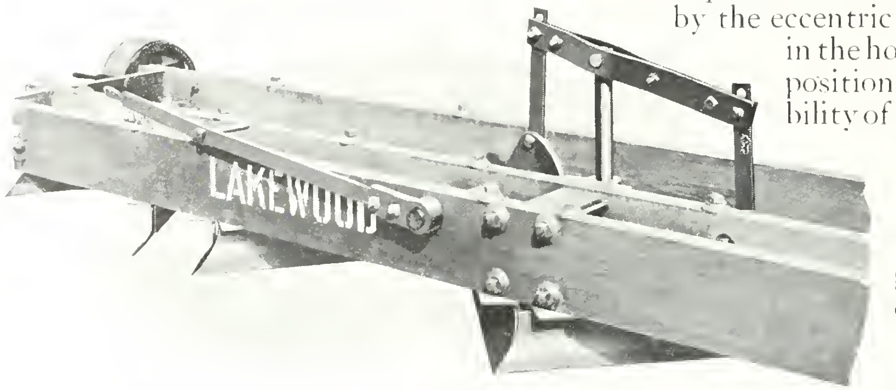
There should be six long and six short angles, and twelve long and twelve short blades with each subgrader shipment.

The machine can be changed from any width to any other width up to and including 22 feet by obtaining only the cross timbers.

When changing the width of the machine, the bolt holes shown in black on this diagram should be used for fastening the angles to the frame.

listed on the bill of lading have been received in good condition. Should any part be missing or damaged, the shortage or damage should be noted on the expense bill by the freight agent before the shipment is accepted. Immediate steps should be taken to file claim against the railroad for the shortage or damage noted.

Before a Subgrader is delivered to the railroad, the shipment is carefully checked at the factory. The railroad acknowledges receipt of the complete shipment in good condition as evidenced by the bill of lading. The Lakewood Engineering Company can not, therefore, be responsible for damage or shortage which occurs after the shipment has passed out of our control into the hands of the railroad. We do, however, welcome the opportunity of being of assistance to customers who have filed claims against the railroad for shortage or damage and will do everything we can to help in such cases. To do so, the original expense bill, with the freight agent's notation of the shortage, must be furnished us.



Assembly of turntable from front of machine. The two holes in the ends of the upright links permit adjustment of the lift of the turntable for different depths of subgrade. The lower holes are used for subgrades from 7 to 10 inches deep, and upper holes for depths less than 7 inches.

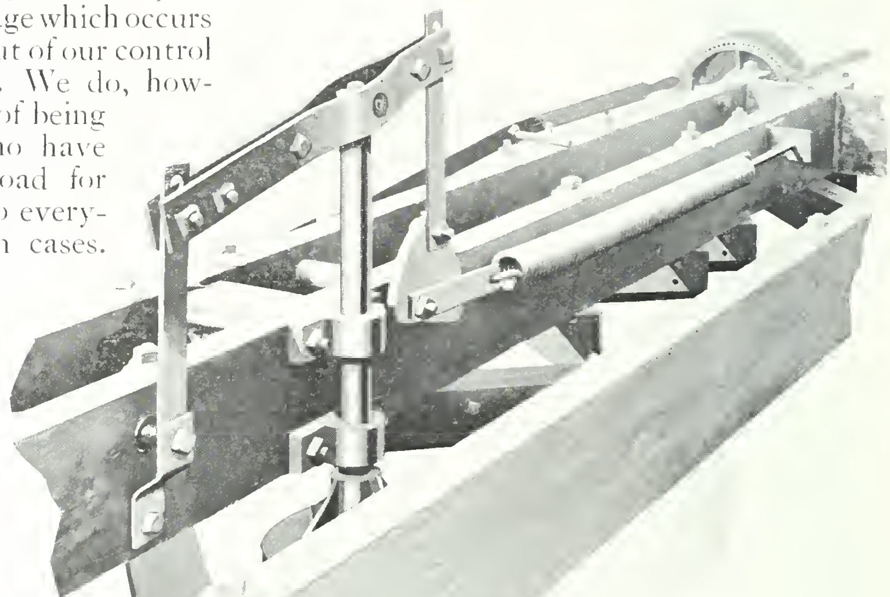
The photographs reproduced here show clearly how the Subgrader should be assembled.

Adjustment for Depth of Cut

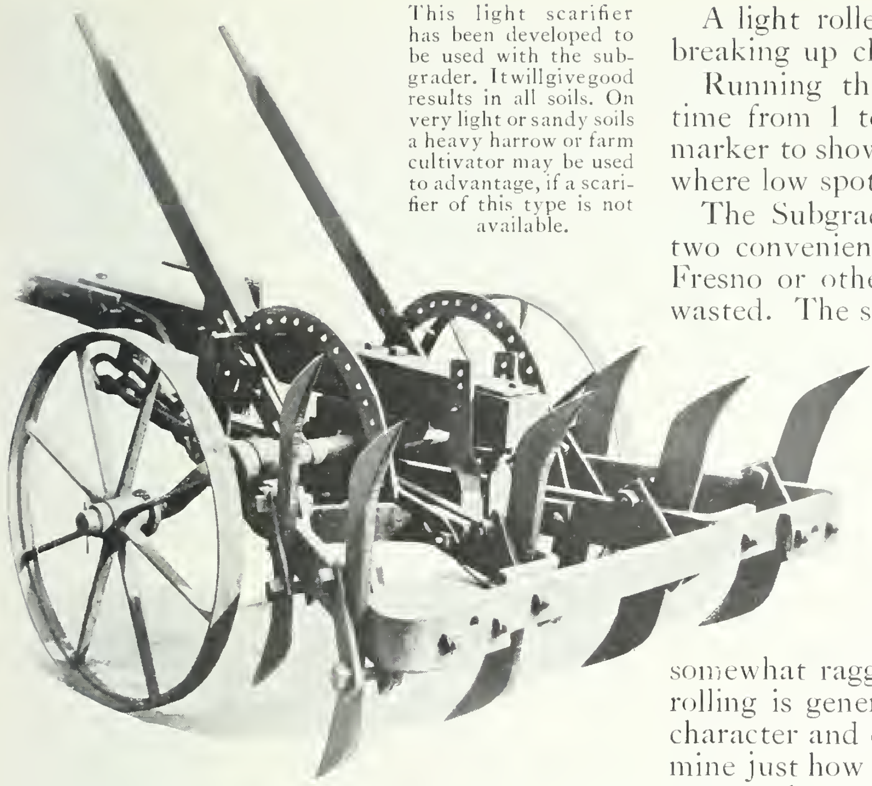
The machine can be adjusted for a subgrade from 5 to 10 inches deep below the top of the side forms. There are two sets of holes in the bearings for the axles. For subgrade depths from 5 to 8 inches the axles should be set nearer the bottom of the timbers. For cuts of from 7 to 10 inches below the side forms, these axles should be set so that they are carried higher, which in effect, lowers the frame. There are also two sets of holes for bolting the blades to the angles which permit additional adjustment of the depth of cut. All working adjustments are made by the eccentric levers. A bolt should be placed in the hole of the quadrant for the lowest position to be used, to prevent the possibility of the Subgrader cutting too deep.

Attaching the Cable

The hauling cable hooks to the front corners of the Subgrader. An eye in the middle of the cable attaches to the tractor or roller. The roller should always be kept close to the center of the road when pulling the Subgrader. The hauling cable as furnished allows the Subgrader to drag at the proper distance behind the roller. No attempt should be made to shorten this hitch.



The turntable as seen from rear of machine.



This light scarifier has been developed to be used with the subgrader. It will give good results in all soils. On very light or sandy soils a heavy harrow or farm cultivator may be used to advantage, if a scarifier of this type is not available.

A light roller may be used to advantage in breaking up clods after scarifying.

Running the Subgrader through the first time from 1 to 2 inches high will serve as a marker to show where there is excess earth and where low spots exist which must be filled.

The Subgrader leaves the earth it cuts in two convenient windrows to be moved by a Fresno or other scraper to the low spots, or wasted. The second cut should be made with the Subgrader set to cut to within about one-half inch to 1 inch of the finished grade, and the surplus earth again moved to the low places, if any exist.

If, after the second cut, the soil is dry, a light sprinkling with water will give it a desirable workability. If the first two cuts have left the grade somewhat ragged in appearance another light rolling is generally to be recommended. The character and condition of the soil will determine just how many more cuts the Subgrader must make to take off the last inch or half inch and bring the grade down to the exact profile.

In easy, smooth-cutting soils the third cut only may be necessary, but if there is any tendency of the soil to tear, or to be gouged out by the blades, two or three additional cuts will be decidedly better. As a rule the final cut should be not more than one-eight of an inch. That is about what is secured by dropping the levers

Side Form Requirements

Good side forms, well staked and substantially supported, are required for satisfactory operation of the machine.

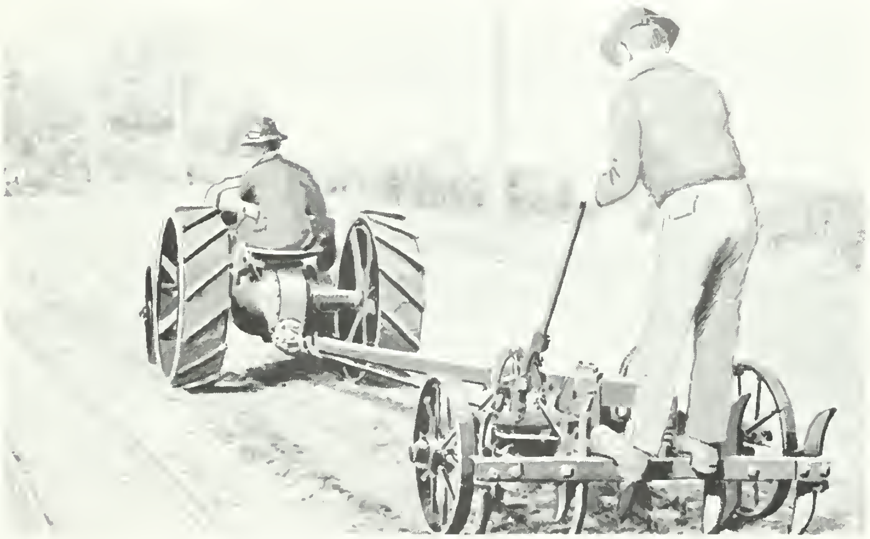
On a concrete road at least 400 feet of forms should be set in advance of the concrete mixer.

When using the Subgrader, the rough grade should be completed in accordance with the specifications. The rough grade should be thrown up for the full width of the road, and from 1 to 2 inches high.

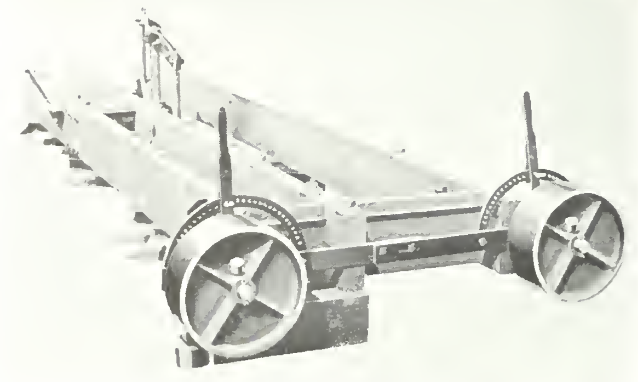
It will be found cheaper to leave a little too much earth than not enough. Too little would require bringing in more earth as the work progresses, or widening the shoulder after the pavement is finished.

Operation

The subgrade between the forms should be thoroughly scarified and the clods broken before the Subgrader is started.



The subgrade between the forms should be thoroughly scarified before the Subgrader is used.



Assembly of wheels, quadrants and levers on left end of machine. When planing the subgrade, the depth of cut is regulated by moving these levers one hole or more for each cut. It is important when moving the levers to move them all the same number of holes.

The surplus earth that is planed off is left in two convenient windrows behind the machine.

on the quadrants only one hole. A little experience soon shows just how many cuts are required and how deep each cut should be.

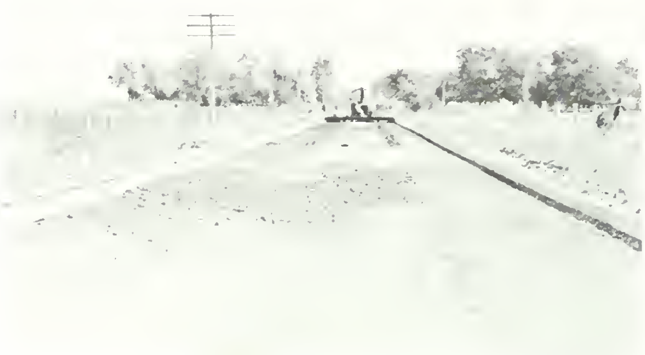
The Turntable

A turntable is provided on the Subgrader for reversing it and turning it lengthwise of the road to allow the roller to pass. This turntable is brought to bear on the subgrade by using a jack lever on the front of the machine. When this lever is thrown over, the machine is lifted clear of the forms and may easily be turned. A heavy coil spring, as shown, makes it possible for one man to raise or lower the machine on this turntable with little effort.

On roads less than 16 feet wide, there may not be room enough for the roller to pass when the Subgrader is turned lengthwise in the middle of the road. In this case, the Subgrader should be raised on the turntable, turned lengthwise, and 4x6 inch timbers placed under the rollers. The machine should then be lowered on these timbers, and moved to the side of the road. Then raise the machine again and remove the timbers to give clearance for the roller.

Crowned Subgrade

When the Subgrader is to be used on a crowned subgrade, this crown as specified is cut in the cross-timbers before the machine is shipped. All the cutting edges of the blades must be kept the same distance from the bot-



The earth which has been planed off is used to fill low spots in the subgrade. The excess is then wasted outside the forms.

The finished subgrade will be to exact depth at all points.

The Subgrader is raised on the turntable by the jack lever on the front of the machine, and turned lengthwise of the road to allow the roller to pass. This is easily done by one man.

tom of the timbers. Any slight adjustment of the blades to accomplish this can be made by shimming under the blade angles.

Operating Crew

Where the Subgrader is used, the subgrading gang should be kept about a full day's work ahead of the mixer. This means that forms should be set for 400 feet in advance of where concrete is being placed, and the subgrade completed for this distance.

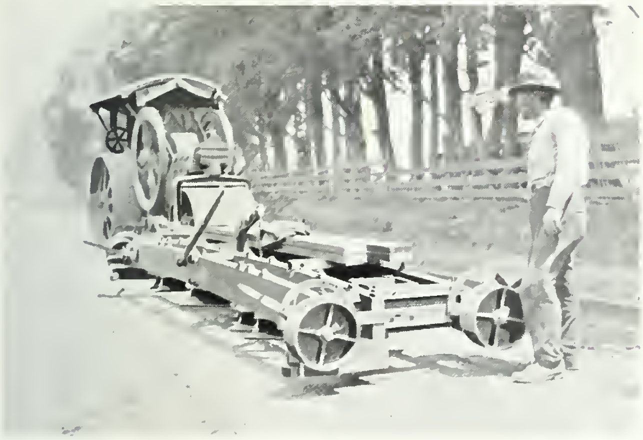
The Subgrader crew will also do the following work:

1. Set steel forms;
2. Take up steel forms and carry ahead for each relaying;
3. Clean forms;
4. Prepare concrete for curing.

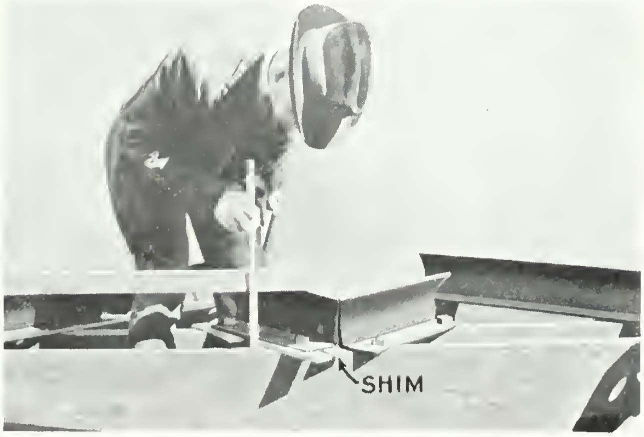
Thus one crew will take care of all the work incident to setting of forms and the fine grading where the Subgrader is used. Efficiency of operation will be obtained only when the organization is made on this basis.

The average crew for such work will generally consist of:

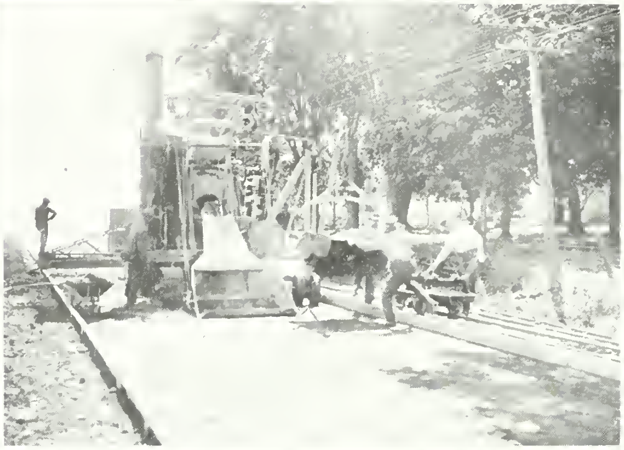
1 Foreman
1 Roller engineer
1 Head form setter
2 Helpers for form setter
6 Laborers.



The timbers on which the machine is rolled to one side of narrow roads, to allow the roller to pass, are carried on the Subgrader.

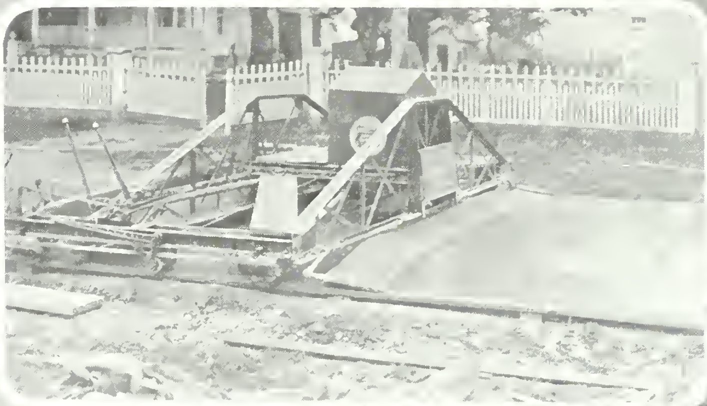


For crowned subgrades, the crown is cut in the timbers. All the cutting edges of the blades must be kept the same distance from the bottom of the timbers. Small adjustments to do this are made by shimming under the blade angle.



LAKEWOOD
BUILT
TO
LAST

LAKEWOOD Road Plant operates in wet as well as in dry weather. The two views at the left show Lakewood plant owned by J. J. Dunnegan on 13-mile road job in Illinois. Lower left picture shows a 1920 Model Lakewood Finisher used by Ross P. Beckstrom on the Cherry Valley Road, near Rockford, Illinois.



Better Steel Forms

for

Concrete Road Construction
Curb and Gutter Work
Sidewalks, Culverts
Fence Posts, Walls
Foundations

Bulletin No. 36

The Lakewood Engineering Co.

Cleveland, U. S. A.

Announcing
Lakewood-Hotchkiss Steel Forms

SINCE 1909 the Hotchkiss Metal Products Company has been making steel forms for all kinds of concrete construction. During his experience of over 20 years as a contractor, Mr. M. S. Hotchkiss specialized in concrete work. He saw the need for better forms--he realized the many advantages of using metal forms--and from his long, practical experience he developed the steel forms here described.

In the development of these forms an ideal has been kept in mind--to produce a better form that would make possible better concrete work and to produce that form at a reasonable price to the user.

That these ideals have been fulfilled are evident to the many contractors who have used these forms.

It is with pardonable pride that The Lakewood Engineering Company announces the Hotchkiss line of steel forms--the result of over 20 years of contracting and 12 years of manufacturing experience.

Lakewood-Hotchkiss Steel Forms are offered as a part of the Lakewood line of general construction and road building equipment, effective at once.

February 17, 1921

Lakewood-Hotchkiss Steel Forms for Concrete Roads

A road form serves three functions

First. It is the mold which retains the freshly poured concrete in place until it hardens sufficiently to stand alone;

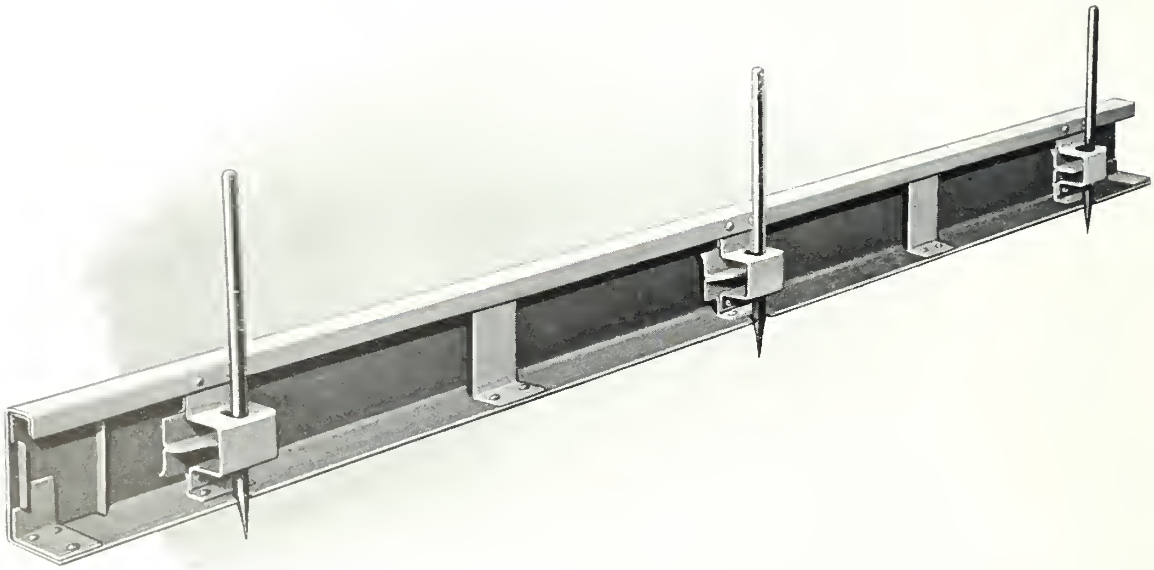
Second: It acts as a templet to which the top of the pavement and the subgrade may be struck off or finished accurately to the profile; and

Third: It must be a substantial support or carrier for the finishing tool, whether it be a hand strike off, or a machine.

Up to a few years ago the first two functions were the only ones fulfilled by the form. Finishing and subgrading machines had not been invented, and the necessity for the forms to act as substantial rails to carry these heavy machines did not exist. Since The Lakewood Engineering Company introduced the Lakewood Road Finishing Machine, and the Lakewood Subgrader, we have constantly been interested in the design and proper setting of the new types of road forms used by contractors.

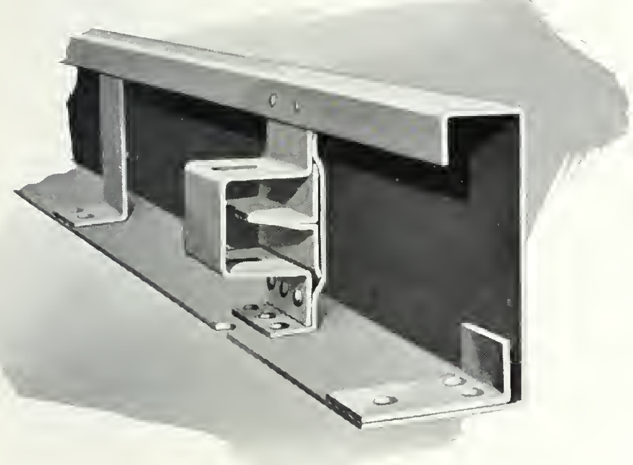
Lakewood has constantly urged the need for better forms, and more care in their installation.

Recent tests by the Office of Public Roads at Washington, and by the highway departments of several states, have shown the tremendous importance of having the wearing surface of a road perfectly smooth, and free from waves or rough spots in the surface. It has been proven that such defects are largely responsible for the rapid breaking up of a road when traveled over by heavily-loaded, fast-traveling vehicles. Engineers are becoming, each year, more strict in that clause of their specifications which reads that a straight edge shall be placed longitudinally on the finished surface of a road, and the road shall be considered imperfect if at any point the straight edge lies more than one-eighth or one-quarter of an inch above the surface.



Three stake pockets and two intermediate braces to each 10-ft. section give strong, rigid support. No rivets in top of form

It used to be general practice to use some suitable size of lumber for side forms. The form was used only as a guide for the strike-off member. Finishing was done by roller and belt method, which in no way disturbed the forms. It was not possible, with such finishing methods, to procure the perfect road surface which may be had with a finishing machine, which strikes off, tamps and belts to the top of the forms as a guide.



Clip which engages joint slide gives extra strength at end of form and prevents damage from rough handling

It is only within the last year or two that subgrade machines have been in use. They shave the subgrade to exactly the right depth below the top of the form, so that the concrete slab when poured will have exactly the right thickness. The contractor is assured that he is not pouring more cement than the plan requires. The engineer is assured that he is getting the full specified thickness.

There has been a constant improvement in forms within the last two years to bring them up to the strength and quality required by these new practices in mechanical finishing and subgrading. Forms have been made heavier. They have been made stiffer. Much more attention has been given to seeing that they rest solidly on the ground. Great care has developed in the way in which they have been staked down. It is essential that the form will remain as set, even under the load of a finishing machine weighing 3,000 pounds, or under a subgrader roughly hauled by a road roller.

We now offer the Lakewood-Hotchkiss Road Form, as the result of three years' study of what road forms should be, to meet the service required in modern road construction.

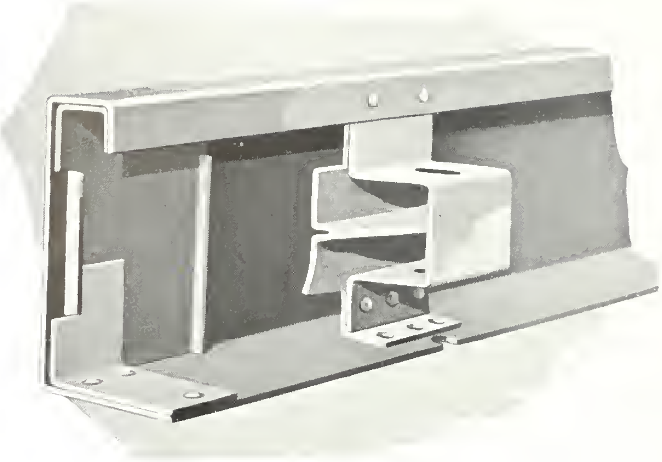
Features of the Lakewood-Hotchkiss Road Form

Lakewood-Hotchkiss blue annealed, high carbon steel road forms are furnished in sections 10 ft. long, and in the heights for road thicknesses of 5, 6, 7, 8 or 9 inches.

The distinguishing feature of the design is that a somewhat lighter metal has been used for the main section of the form, but this section has been reinforced by stiffening members, advantageously placed. Each 10-ft. section has the top flange supported at five intermediate points by a heavy stiffening iron.

This principle is the same as is used in bridge design, where light members are riveted together to form a strong truss, rather than using one solid heavy section of sufficient strength to carry the load.

Form clamped to stake with locking wedge which is a permanent part of the form



Sections of form solidly locked together with close-fitting metal slide extending from bottom flange, up to and under head of form

Lakewood-Hotchkiss Road Forms also are different in that electric spot welding is used in addition to riveting to fasten the various members of the form together.

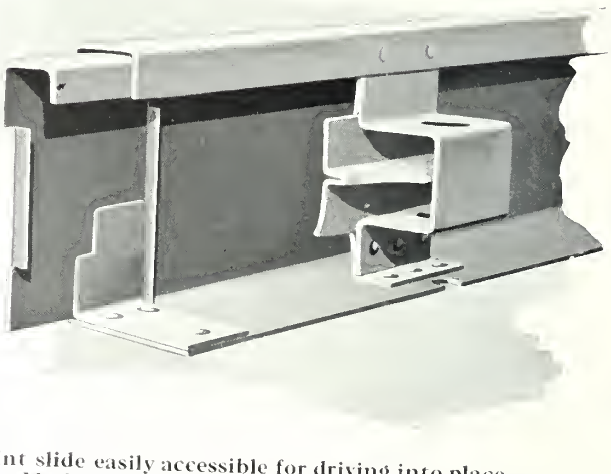
The Lakewood-Hotchkiss Road Form has a bottom flange 4 in. wide, giving a large bearing area on the ground. The top flange is $2^1/_4$ in. wide, which is ample as a rail for the finishing or subgrade machines The turn-down section of the top is $1^3/_4$ in. deep, making for unsuaul strength at this point.

The forms are staked to the ground with three stakes to each 10-ft. section. The stake pockets have elliptical holes giving considerable leeway when driving the stake, so that it does not disturb the alignment of the forms. After the stake has been driven until its head is about an inch and a half below the top of the form, so that the stakes will not interfere with the finishing machine wheels, the form is clamped to the stake by a heavy wedge member sliding in the stake pocket. This wedge is heavy enough to allow driving with a sledge hammer. It has a quarter-inch bearing on the stake, and cannot become bent or rapidly worn. These wedges may, however, be easily replaced when worn, They are held in the pockets and cannot become lost on the job.

Lakewood-Hotchkiss Forms are built so that any section may be removed from a line of forms set up to allow passage of trucks or other contractors' tools. There is an extra heavy slide, at the joint, which holds the forms in alignment, both laterally and vertically, and assures a smooth joint between the forms over which the finishing machines may run. These slides are extra heavy, and so located as to be accessible for driving with hand hammer when setting up or taking down the forms. It is to be noted that the top of this slide accurately fits into the channel shaped head of the road form. It can be definitely stated there will be no opening of the forms at the joints because of the careful working out of the details of this locking device.

There are no rivets in the top flange of the form to get worn and loose under the wheels of the finisher or subgrader.

The sections of form are made from steel especially milled to size for each height of form. The rolled edges of the top and bottom flanges are so smooth that a man cannot cut his fingers while handling the form. It is the form with the velvet edge.



**Joint slide easily accessible for driving into place
Made extra heavy to stand hard service
Reinforces head of rail at joint**

Lakewood-Hotchkiss Steel Forms for Curbs, Gutters and Sidewalks

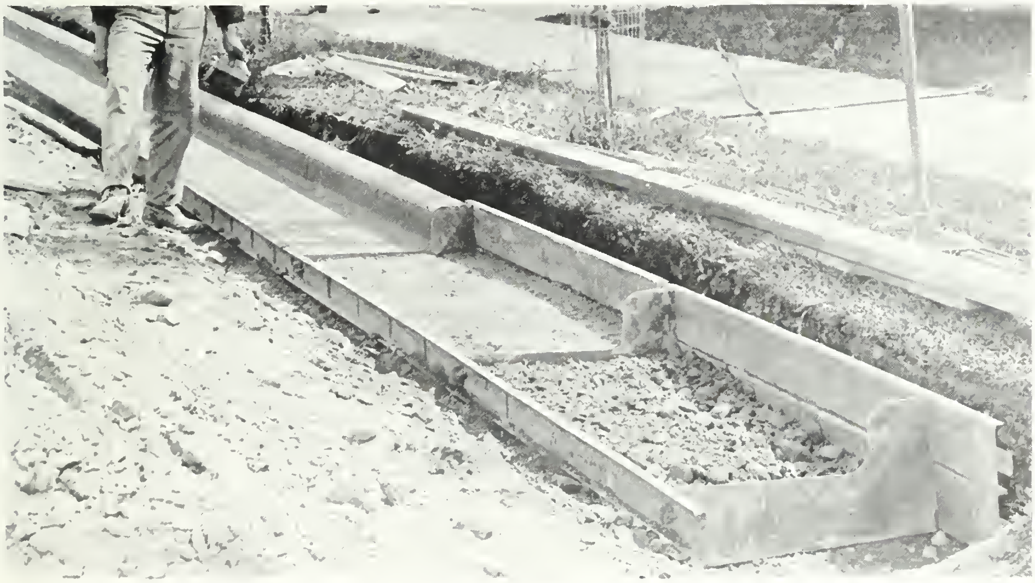
The Lakewood-Hotchkiss method combines the use of a better form and a better method, resulting in more nearly perfect concrete work. The design of the forms is such that the same side rails can be used for curb, gutters, sidewalks, foundations, culverts, etc. Thus, with a comparatively small investment in Lakewood-Hotchkiss Steel Forms, a contractor can use this equipment for practically any kind of work on which he cares to bid.

The same side rails are used for all kinds construction

One of the attractive features of Lakewood-Hotchkiss Steel Forms is the simple locking device which makes the entire form a strong substantial unit without the use of bolts, stakes or braces. This is accomplished by locking the division plates to the side rails with a wedge key, as illustrated.

That the use of the Lakewood-Hotchkiss system insures a more nearly perfect concrete and gives an absolutely perfect expansion joint can be readily appreciated from the following discussion. In the first place this system allows the removal of the side rails and dividing plates 20 minutes after the concrete has been poured.

To employ the Lakewood-Hotchkiss system successfully a fairly dry mixture must be used. As it has been generally agreed that a dry mix makes stronger concrete than a wet one, this is an advantage.

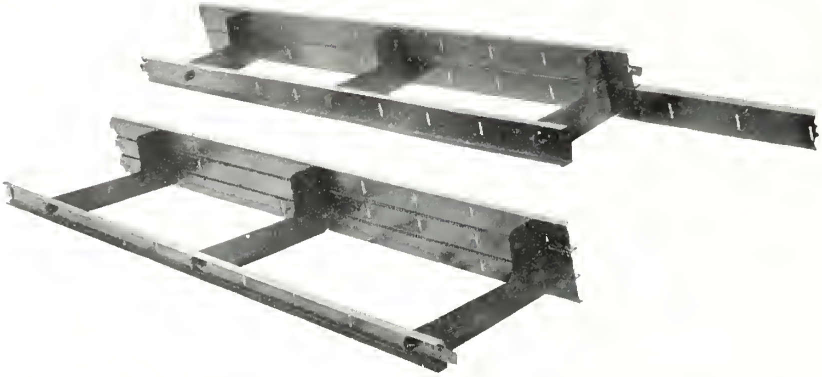


Using a dry mixture results in a dense concrete of maximum strength. The forms may be removed 20 minutes after pouring

It is also generally agreed that a good, dry mix, when allowed at least 20 minutes to take initial set, is stiff enough to stand without support.

If this is true, no harm can result from removing the side forms 20 or 30 minutes after pouring. Furthermore, as the concrete will stand up when the side rails are removed, it is absolutely certain that the concrete surfaces will not come together when the dividing plate is withdrawn. Thus an absolutely perfect expansion joint is bound to result.

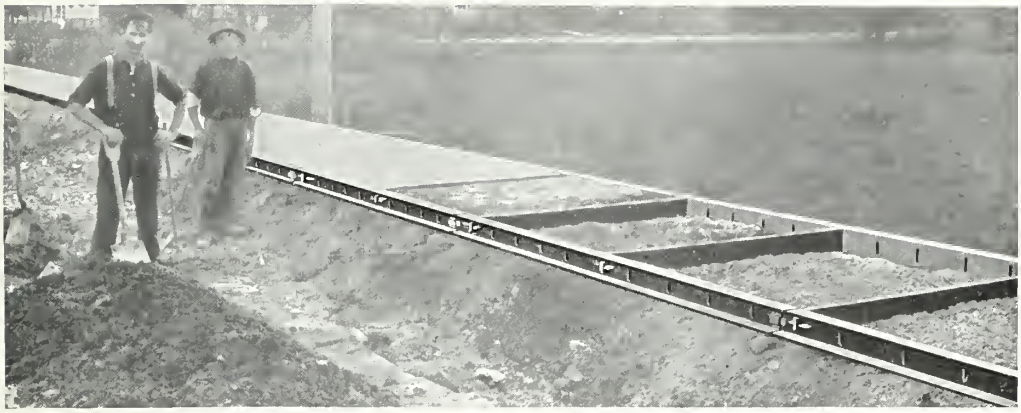
This curb form is typical of Lakewood-Hotchkiss steel forms in that the form is a strong, substantial unit, using no bolts, stakes or braces



Templates for Lakewood-Hotchkiss forms can be furnished quickly to meet any specifications for curb, gutter and sidewalk construction

Being able to remove the forms quickly, thus getting maximum service from his equipment,

A perfect expansion joint is assured when the Lakewood-Hotchkiss method is used. The dividing plates are removed last

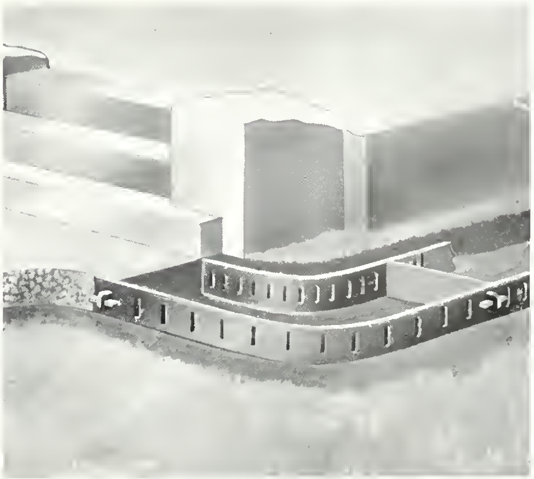


Lakewood-Hotchkiss sidewalk forms are held rigidly in place by locking the dividing plates into the side rails. Each square is uniform and the alignment perfect

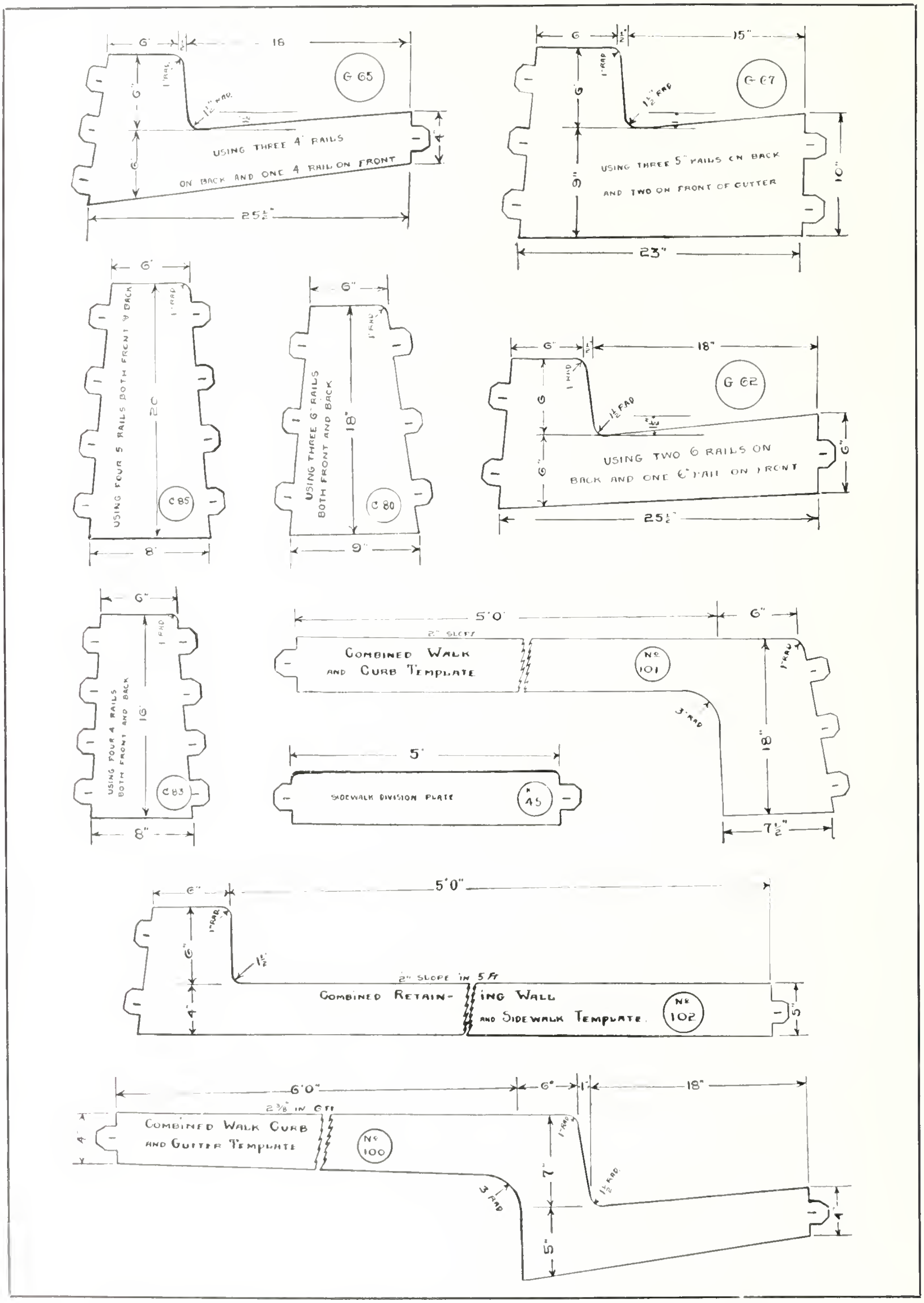
a contractor using the Lakewood-Hotchkiss method reduces his investment in forms to the minimum.

Another big advantage to the contractor of Lakewood-Hotchkiss Forms is the ability to use the same side rails for various kinds of work. To illustrate, let us suppose that a contractor has a supply of 5-in. side rails, 10 ft. long which he purchased for sidewalk construction. After completing the walk he secures a straight curb job, which we will suppose to be 20 in. deep, 8 in. on the base, and 5 in. on top. To complete his outfit, the contractor simply orders a few curb templates to correspond to the cross-section of the curb. The 5-in. side rails are built up 20 in. high and securely locked into a strong substantial form by the Lakewood-Hotchkiss locking system.

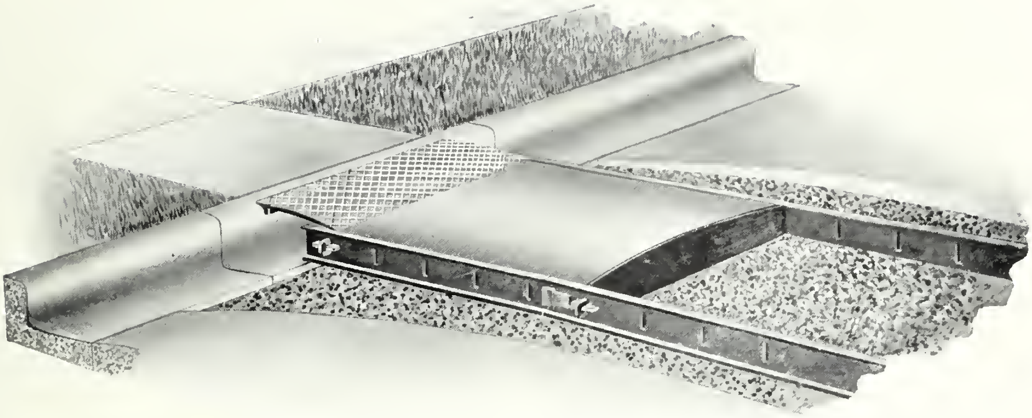
The next job, we'll say, is a combined curb and gutter, a cross-section of which may call for a template 15 in. on the back of the curb and 10 in. on the face of the gutter. Using the Lakewood-Hotchkiss method, the contractor orders a few curb and gutter templates and his outfit is again complete. Three of the 5-in. side rails make up the back of the form and two 5-in. rails give a 10-in. gutter face.



(Left) Lakewood-Hotchkiss forms, using 6-in. radius corners, to make approach from street to residence. (Right)—Spring steel flexible sections simplify complicated curved work and eliminate tedious sawing and fitting



Lakewood-Hotchkiss dividing plates or templates can be furnished quickly to meet any specifications. Several typical ones are illustrated



Lakewood-Hotchkiss forms lend themselves to all kinds of curb, gutter and crosswalk construction

From this it is readily seen that, being able to use the same side rails for various kinds of work, the contractor using Lakewood-Hotchkiss system has a minimum amount of money tied up as an investment in forms. In addition, he has the advantage of all the well known economies of using steel forms.

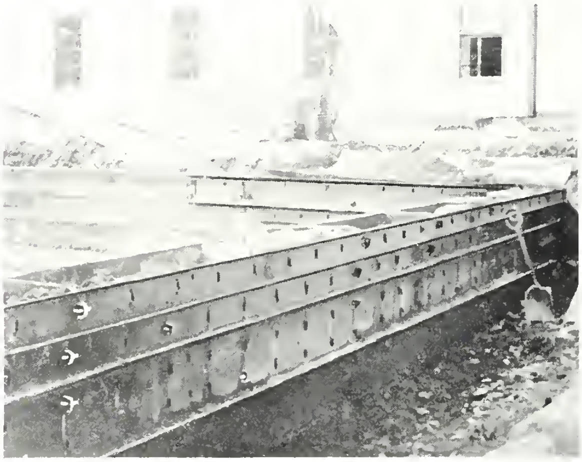
Lakewood-Hotchkiss side rails are carried in stock in 4, 5, 6 and 12-in. sizes. Dividing plates to meet any specifications can be shipped by express three days after receipt of order.

A special high-carbon blue annealed steel is used in all Lakewood-Hotchkiss forms, giving a lighter form just as strong as a heavier form of softer steel. And because plates for Lakewood-Hotchkiss forms are rolled to exact size, there are no sharp, sheared edges—the forms can be handled without danger of the men cutting their fingers. All side rails are slotted every twelve inches and are fitted with end connections. With this frequent slotting most any condition can be met by inserting dividing plates or stop plates at any desired point.

Several typical dividing plates are illustrated. When ordering dividing plates, or templates, as they are sometimes called, kindly note the illustrations carefully to see that your description is as complete as those shown.

Curved walks and intersections easily built the Lakewood-Hotchkiss way

Lakewood-Hotchkiss Steel Forms for Foundations, Walls and Culverts



The same Lakewood-Hotchkiss side rails as used for curbs, gutters, or sidewalks are used in wall construction

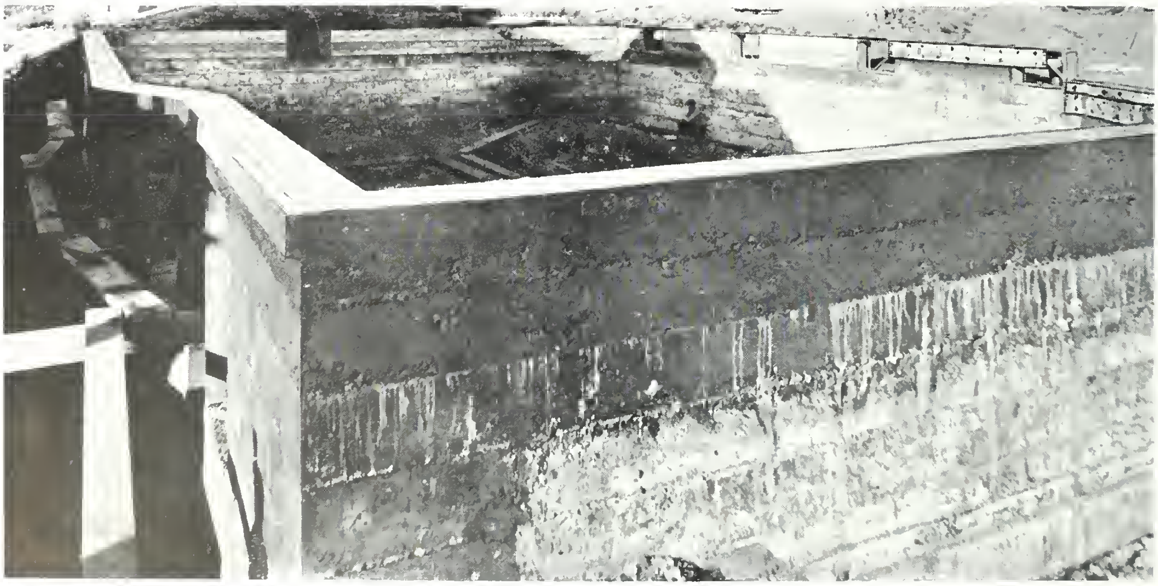
The Lakewood-Hotchkiss method of wall construction closely follows the regular method of wooden form construction, but eliminates all waste of material and labor, the need for upright supports, and fitting and sawing.

In wall construction the standard 10-ft. channel sections, 6 or 12 in. wide, are commonly used. Other widths may be used. To hold these side rails accurately to the width of the wall, narrow, locking tie plates are inserted in the vertical slots in the side rails.

The flanges of the side rails are punched for inserting the pins where necessary. This, however, is not usually necessary except when three or four sections are placed one above the other before filling.

The sections may be assembled and then lifted to position or may be assembled right in place. The slip tongue and socket connections permit removal of any of the rail sections without interference.

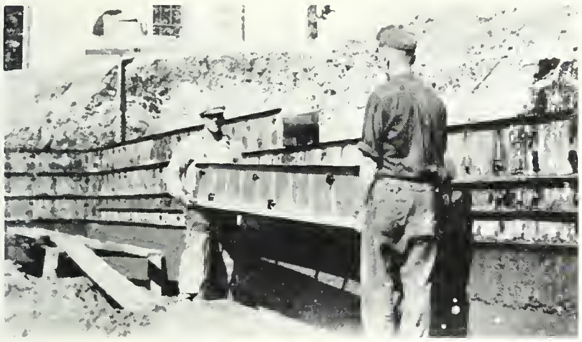
The locking tie plates are made as narrow as practical and slightly tapered with shoulders, so that when keyed through the

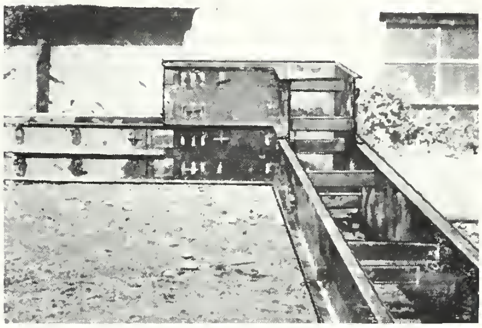


A fine job—and all the waste in lumber and labor saved by using Lakewood-Hotchkiss Steel Forms

Perfect angles made easily and economically the Lakewood-Hotchkiss way

tongues of the tie plates the channels are drawn firmly against the shoulders of the tie plates. Thus the whole form is held securely together and in alignment. The taper allows the tie plate to be easily withdrawn from the concrete.

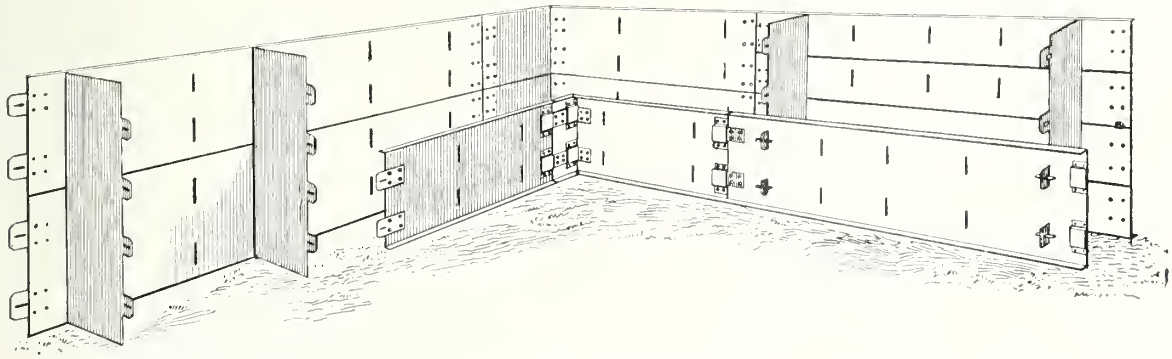




Each section of Lakewood-Hotchkiss forms is a unit in itself. The units can be lifted to position or assembled right in place

Locking these forms with narrow tie plates and pulling them horizontally through the wall is new and original. It surprises the builder to see how efficient and practical it is. By this principle every shovel full of concrete placed holds the forms in more perfect position and alignment, without bolting, bracing, or otherwise sustaining them.

The corner sections are uniform and are made the same width as the channel rails. These are so constructed that the two ends of the angles are brought up square and fit nicely into the intermediate sections. They are held by slip tongue connections, the same as the regular wall channel rails. These corner sections are also locked with the same



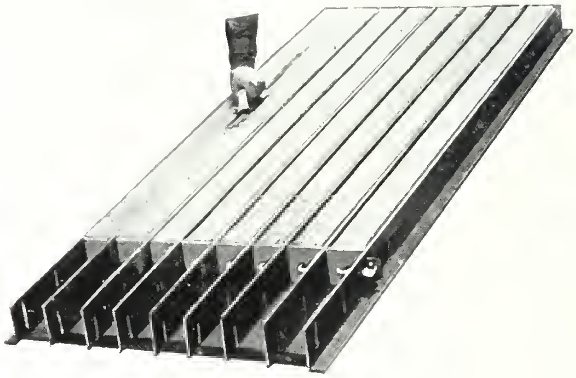
The Lakewood-Hotchkiss principle is the same for wall construction as for curb and gutter work. The same side rails and method of locking are used throughout

narrow locking tie plates and can also be assembled and then raised in position on the wall.

To more minutely describe the corner sections, the outside channel rails are intended to take up 3 ft. of space on the building line, and the inside channels 2 ft. on the inside line, on a wall 1 ft. wide. One of the outside rails is 3 ft. 6 in. long; the other outside rail 3 ft. 0 in. long. The 3-ft. rail has tongues on one end which connect in the vertical slots of the other outside rail at the 3-ft. point. This makes a perfect right angle. These rails are so slotted, however, as to easily provide for an adjustment in the width of the wall when desired, without changing the entire corner section.

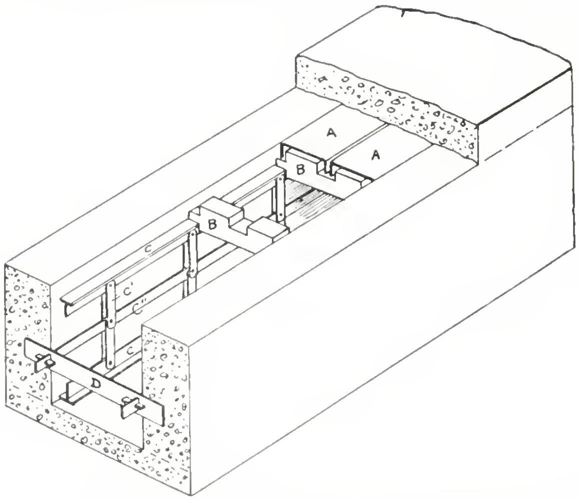
To more fully describe the working operation of these wall forms, and to show the practical efficiency in actual use, suppose the first section is set in place. It can be either 6 in. or 12 in. in depth. As fast as the form is filled the next section is raised in position, resting on the flanges of the section just filled. This also is rapidly filled and when this is completed, you can tap out the locking keys and remove the lower channels, at thesame time pulling the narrow locking plates through the wall. The channel sections thus removed are ready for replacement on top of the last section filled. This process is continued until the desired height is reached.

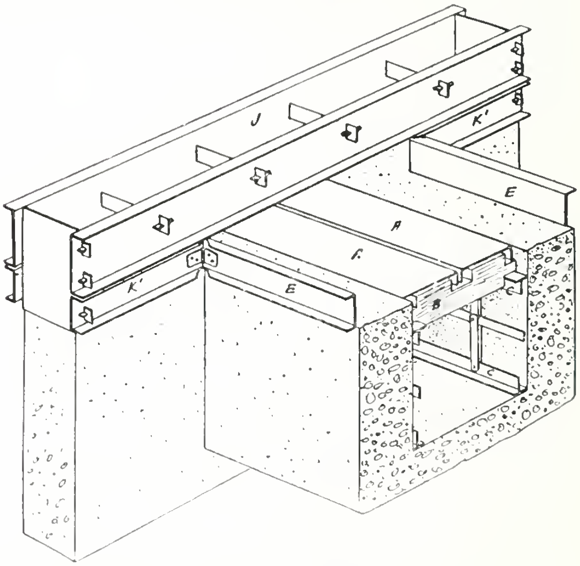
It is the same Lakewood-Hotchkiss principle of placing, filling, removing and replacing a rapid, continuous operation, making steel forms in every construction an economical proposition.



Lakewood-Hotchkiss Post Form

To work to best advantage for rapid construction you should have intermediate sections of different lengths, so that the forms may be erected around the entire building, unless the building is larger than your equipment would care for. In this case the erection may be carried to any point in the building line and a stop-plate locked in the form. To illustrate, if the building is 36 ft. x 26 ft. no intermediate short sections would be needed as the corner sections would take up 6 ft. of





(Left) Collapsible support in working position for culvert construction. (Right) Forms set for construction of roof and parapet wall

the building line. Hence you would require three regular 10-ft. sections on each side and two regular sections on each end. If the building is 42 ft. on one side you would need three regular sections and one 6-ft. section to fill out this space on accurate measurements. The space may be varied also by slipping in flat plates where the building line makes a difference in inches. A little careful study in this connection will show how nicely this method can be worked out.

These wall forms can be used to good advantage where the work will permit of conveying the concrete by means of chutes, or when portable scaffolding arrangements are used.

For culvert construction the same side rails are used as in curb, gutter, sidewalk and wall work, in connection with the Lakewood-Hotchkiss collapsible support. The same Lakewood-Hotchkiss method of locking the forms is also employed, the narrow locking tie plates being pulled horizontally through the wall instead of vertically so that concrete of any consistency may be used. Header wall connections are so constructed that they will connect perfectly with the throat walls and, at the same time, give header walls and parapets parallel to the street. The collapsible support, and other details, are shown in the line drawings.

Post forms, also, are included in the Lakewood-Hotchkiss line of steel forms. These post forms are adjustable in lengths. Forms are removed without disturbing the posts until the concrete has set. Made in batteries so that 5 or 10 posts can be poured at one time. The same form is used to make plain or ornamental posts. The posts can also be cored in the forming to permit bolting on of steel or wooden pieces such as guard rails etc. The division plates are held securely in place by connecting with the end plates. The whole form is rigidly locked by wedge-shaped steel keys.

The Lakewood Engineering Company, Cleveland, U. S. A.

Branch Offices

Atlanta	90½ N. Forsyth St.
Baltimore	American Bldg.
Buffalo	256 Main St.
Chicago	Lumber Exchange Bldg.
Cleveland	Racine Bldg.
Dallas	Sumpter Bldg.
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Memphis	Central Bank Bldg.
Milwaukee	Milwaukee Athletic Club Bldg.
Minneapolis	529 Second Ave. South
New York	141 Centre St.
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Pittsburgh	Union Arcade
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Smith-Booth Usher Co.	228 Central Ave., Los Angeles
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R. B. Everett & Co.	3118 Harrisburg Blvd., Houston, Tex.
Waldo Bros. & Bond Co.	181 Congress St., Boston, Mass.

Patent Notice

The devices described in this publication are protected by patents and patent applications pending.

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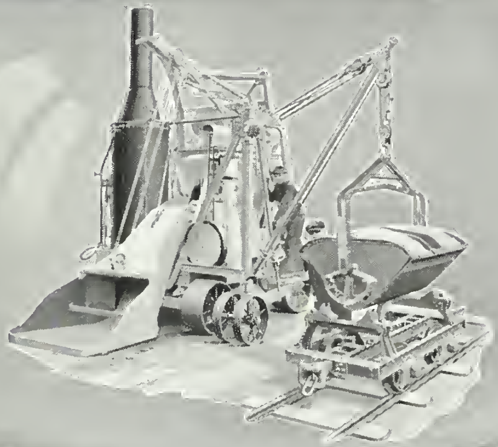
Bulletin No. 29-D

LAKEWOOD

CONSTRUCTION PLANT



LAKEWOOD ROAD CONSTRUCTION PLANT

THE LAKEWOOD ENGINEERING CO.
CLEVELAND U.S.A.

Lakewood Service to Road Contractors

Because no two road construction jobs are exactly alike, it is not possible to say what the size or cost will be of the paving plant needed for the work without a thorough study of the conditions to be met.

Lakewood engineers, specialists in paving plant layout and operation, are at the service of the contractor who contemplates undertaking a large job. Upon request they will gladly assist and advise with him in planning his work and, after a personal investigation, will make an estimate as to the equipment needed, and what the approximate cost of the work will be if handled by the Lakewood method.

This service is given without charge and involves no obligation on the part of the contractor.

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About the Lakewood Engineering Company

The Lakewood Engineering Company was organized in 1896. The business showed a normal growth until late in 1914. Since then the expansion of the company in the development or absorption of other companies has been rapid.

The Duplex Manufacturing and Foundry Company, of Elyria, Ohio, was purchased to give the Lakewood Company its own source of castings.

The Milwaukee Concrete Mixer Company became associated with Lakewood in the early part of 1917, furnishing, through its plant, additional facilities for the manufacture of mixers.

The Marsh-Capron Manufacturing Company, of Chicago Heights, manufacturers of mixers, entered into a similar arrangement in 1918.

The Galion Dynamic Motor Truck Company, of Galion, Ohio, was purchased outright in the fall of 1917.

The rapid development from a comparatively small business in 1914 to millions in 1919 has had as its most interesting and outstanding fact the remarkable ability of the personnel of the organization to grow as fast as the business.

Coupled with this rapid growth and unusual ability is a reputation for loyalty and whole heartedness in the Lakewood organization which is commented on by all visitors. This spirit, we believe, encourages more satisfactory business relations, real co-operation and service.

Foreword

THE present demand for hard surface roads is out of all proportion to our ability to satisfy it. Engineers who must build new roads, and at the same time maintain the old ones, are confronted by the question of how to get the roads built rather than by the problem of raising money.

It is estimated that it would require 166⅔ years to improve all the present mileage at the 1909-1915 rate and 33 years to improve the necessary minimum of at least 20 per cent.

Very evidently the business of constructing roads must be put on the same quantity production, uniform quality, cost-reducing basis as our other manufacturing industries.

Quantity and quality production is possible in our manufacturing plants because the work is systematized. Machines have been substituted for manpower; each worker is given definite tasks to do—day after day—and, by repeating these tasks, becomes highly efficient. Every effort is made to produce a large *quantity* of *uniformly* good *quality* at the lowest possible cost.

In the manufacturing plant raw material is received and stored in a warehouse. This supply of raw material may be great enough to keep the plant running for a month or more independent of railroad deliveries. From the warehouse the raw material is moved to the producing machines, goes through the manufacturing processes until, finally, the finished product is ready for the user.

So, manufacturing processes can really be divided into four operations:

1. Receiving and storing raw material.
2. Transporting raw material to manufacturing machines.
3. Manufacturing.
4. Delivery of the finished product.

The principles on which the operation of the concrete road plant developed by The Lakewood Engineering Company are based are very similar to those which the successful manufacturer follows.

Instead of pig iron and coke, the concrete *road* manufacturer has, as his raw materials, sand, stone and cement. These he must unload and store, providing large enough storage space to make his *road* factory independent of irregular deliveries of raw material.

Instead of hauling pig iron and coke to the cupola, the manufacturer of *roads* hauls sand, stone and cement and pumps water to his manufacturing machine—the *concrete mixer.*

And as the steel manufacturer melts the iron and perfects his finished product, so the manufacturer of *roads* puts sand, stone, cement and water into the concrete mixer and produces *his* finished product—*concrete road.*

The fourth step—delivery to destination—is, for the *road* manufacturer, a simple matter, as the distance his product must travel, is, at most, the length of the boom on the paving mixer.

The Lakewood *road manufacturing* plant involves the use of machines instead of manpower. Quantity *manufacturing* of roads is made possible. Cost of handling and rehandling raw materials is cut to the bone. Waste of materials during the manufacturing process is eliminated. Labor is made more efficient and labor turnover reduced. Uniformity of product is assured at no extra cost. And a better product results—a *denser*, *smoother*, *longer-service* concrete road.

Details of operation and description of the equipment used in *manufacturing roads* by means of the Lakewood system are given in the following pages.

It is hoped that this foreword will help to emphasize the similarity of *road* manufacturing to the manufacture of any other commodity, and will help the reader to visualize the application of modern industrial efficiency to the road manufacturing industry—an industry in which *quantity production* and *uniform quality* have never before been achieved.

And because the use of Lakewood plant makes possible the production of good concrete roads in large quantity, in much the same way as our modern industrial plants operate, we say that with Lakewood plant the contractor *manufactures* concrete roads.

The system is easily applied to laying concrete bases for brick or asphalt roads.

Manufacturing Concrete Roads With Lakewood Plant

(A Description of the Method Employed)

The manufacture of concrete roads with Lakewood plant may be divided into four operations: 1—unloading the raw material (sand, stone and cement); 2—hauling this material to the mixer; 3—mixing the concrete, and 4—finishing the road surface.

Applying the principles of good factory management, the unloading plant must be able to unload quickly to avoid demurrage charges, store enough material to make the operation of the plant independent of railroad delivery, and designed to eliminate waste and costly rehandling.

Unloading and Storing Raw Material

Contrary to the practice of storing material on the grade, the Lakewood method involves the use of a central unloading and storage plant. Typical layouts that can be varied to meet different requirements are shown on pages 10 and 11.

Lakewood Tunnel Storage and Narrow Gauge Haulage System used by the Chicago Heights Coal Company, Contractors at Momence, Ill.

When the layout shown on page 10 is used, gravity storage bins are placed at intervals along the railroad siding with narrow gauge track running under the bins, past the cement shed and thence to the mixer. The material is transferred from cars to bins, or cars to stock piles, by means of a clam shell bucket hung from a locomotive crane.

Space for stock piles is provided, as indicated, to take care of material in excess of the bin capacity and to allow storage of enough material to make operation independent of railroad delivery. The stock pile capacity does not have to be so large as when hauling is done on the sub-grade as only a few stock piles are required and the same piles are used throughout the job.

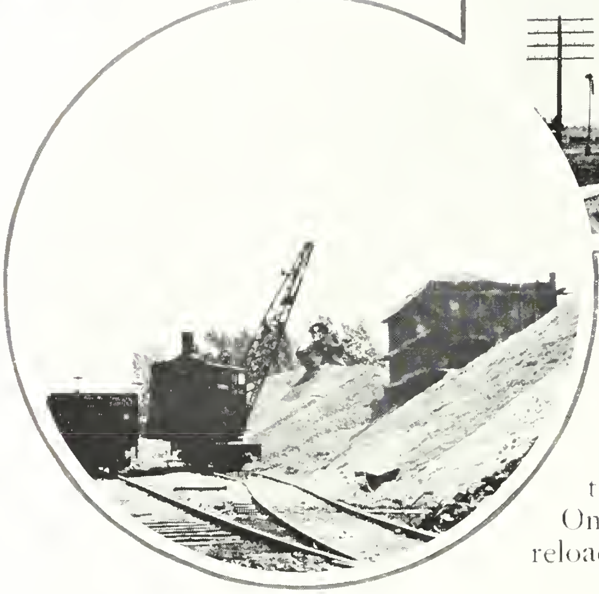
When bag cement is used the bags are transferred from the railroad cars to the cement platform or shed by hand. If bulk cement is used, the cement platform is unnecessary. The bulk cement is received in gondola cars, properly protected by a tarpaulin or tar paper housing. By replacing the cement shed with gravity bins and fitting the bins with removable water-tight covers to permitthe entrance of the clam shell, the cement can be unloaded by the bucket.

At this central loading plant sand and stone are poured from the gravity bins into road cars or batch boxes having separate and properly proportioned compartments for sand and stone and a water-tight box for cement. After a train is loaded with sand and stone it is moved past the cement shed, where the cement boxes are filled.

Whether bulk or bag cement is used, the cement boxes are filled at the central loading plant, covered with a water-tight lid, and the correctly proportioned batches are ready to be hauled to the mixer. As no cement leaves the storage shed, except in the water-proof box in the road car, no sacks are taken out on the grade, saving the cost of taking care of the sacks.

As the locomotive crane is the first

Clam shell bucket hung from crane transfers materials to bins and storage piles. Costly rehandling is avoided.



Large storage piles permit quick unloading, and it is, therefore, possible to release sand and stone cars immediately, thus avoiding demurrage charges. The unloading can be done regardless of weather conditions, which is a decided advantage over the practice followed in the past. Once the materials are unloaded the cost of reloading them into road cars is practically nothing and the loading is independent of the crane. Furthermore, no money is spent for hauling until the materials are actually needed at the mixer. And as practically *all* of the sand and stone can be used (due to having only a few *big* stock piles) waste of material is avoided and aggregates are kept clean.

The unloading plant shown in the layout on page 10 is for use where bins are used. The tunnel arrangement shown on page 11 is a variation to meet the contractor's requirements.

equipment on the job, it can be used to unload other machinery. The material plant can be made ready and operations begun while grading is being done. And as soon as a part of the grade is finished, concrete placing can be started.

Having a flexible, large-capacity plant, capable of utilizing the entire length of the railroad siding, the work is made practically independent of irregular material deliveries.

And with this type of plant practically no hand labor is required and rehandling of material is reduced to a minimum.

Hauling Batches to the Mixer

No construction work is stopped so completely by wet weather as concrete road work, when materials are hauled on the sub-grade in wagons or trucks. Hence, the method advocated by The Lakewood Engineering Company eliminates hauling in wagons or trucks and involves the use of specially designed road cars and narrow gauge track, as indicated by the layouts on pages 10 and 11.

Contractors usually endeavor to overcome the disadvantages of

Work was stopped on this road because the grade was too wet to permit hauling. Cars and track prevent such delays.

Track can be laid on shoulder or sub-grade, thus giving flexible operation to meet every condition. The center picture shows a train operating in wet weather when hauling over sub-grade in trucks would be impossible.

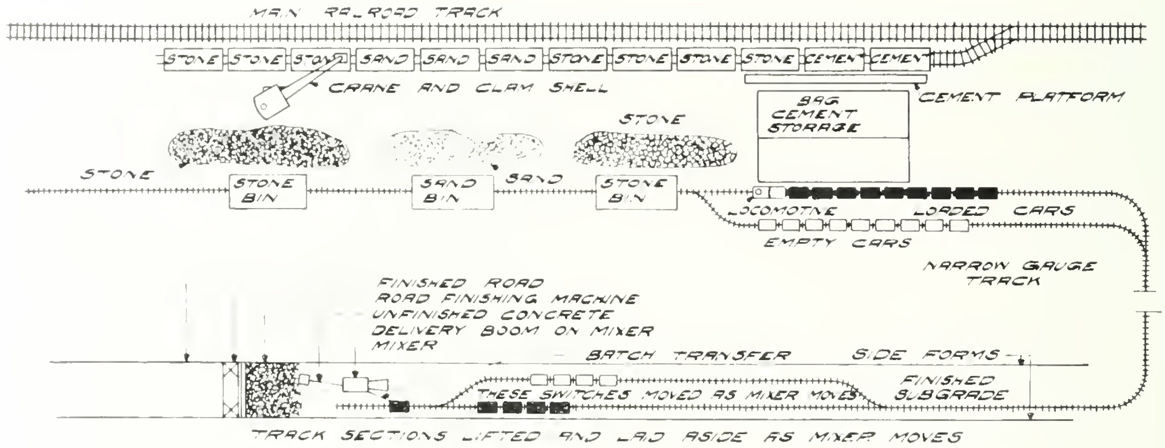
stocked on the grade before concrete placing is begun. This results in a loss of one or two months of valuable time out of a season, before the actual laying of concrete is begun.

By using a central loading plant, unloading of materials and the grading can be started *simultaneously*. And as soon as

(Continued on page 12)

hauling on the grade in wet weather by stocking sand and gravel on the finished sub-grade as far ahead of the mixer as possible. But in doing this the contractor is only partially insuring a supply of the necessary materials. Seldom is cement stored in quantities on the grade. Water is *never* stored on the grade. Therefore, storing sand and stone, but *not* storing cement and water, does not, by any means, free the contractor from delays caused by lack of material at the mixer. The sub-grade is simply used as a place to stock pile *part* of the material. No more wasteful place could be chosen for a stock pile.

To be able to haul on the grade with wagons or trucks a long stretch is usually graded. Bearing in mind that the hauling will have to stop when rain comes, considerable quantities of sand and gravel are



Plant Layout M-231

This plant has the following characteristics: Single track siding; traveling crane having full circle swing handling a clam shell bucket; storage bins for sand and stone from which to load narrow gauge cars; house in which to store cement in bags; narrow gauge track with passing siding on sub-grade.

Stock piles should be large enough to permit operating the unloading plant for several days before hauling begins. The crane unloads sand and stone direct from railroad cars into the bins. When the bins are full and the narrow gauge railway is not operating, the crane immediately unloads from the railway cars into the stock piles and in this way eliminates demurrage charges.

If, on the other hand, the narrow gauge road is operating when no cars have been received from the railroad, the crane rehandles material from the stock piles into the bins. Thus the unloading is independent of the hauling and may proceed regardless of weather conditions or time of day. These features make this type of unloading plant most economical when the yardage to be handled justifies the plant investment.

Bags of cement are stored in the cement house or are emptied directly into the road cars. Hoppers with bin gates and measuring devices may be used economically under certain conditions.

A train of cars is pushed under the stone bin and the stone compartment in each car is filled with that aggregate. The train is then moved to the sand bin and the sand compartments are filled. The watertight cement compartments are filled and the train is ready to be hauled to the mixer.

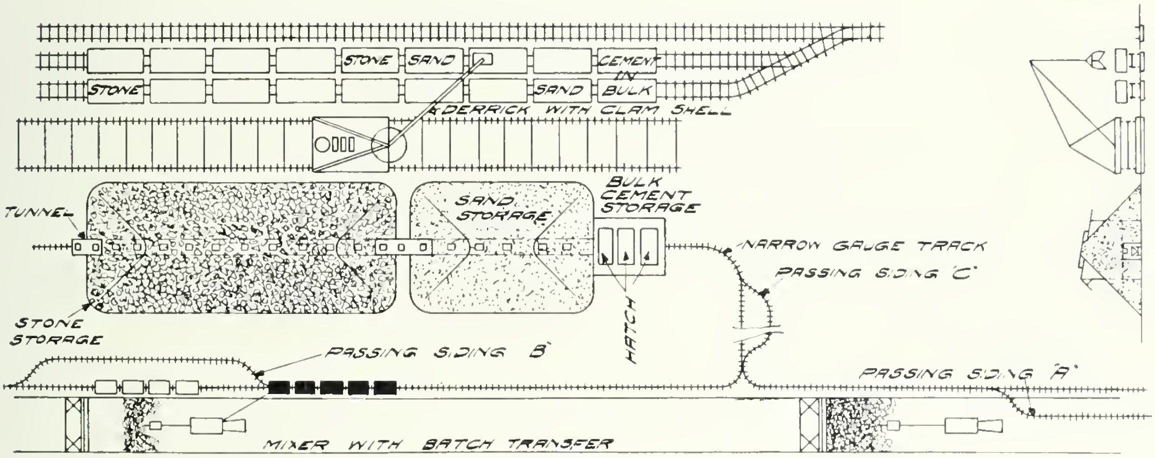
The locomotive places the loaded cars on the track as shown. Cars are handled either singly or in pairs over the stub end of the track to the mixer. The batch transfer lifts the car bodies and dumps them into the mixer as described on pages 12 and 13. The empties are pushed onto the passing siding.

Laying the track on the sub-grade is not recommended. Where possible it should be laid on the shoulder, as shown in Layout M-232. When track is on the subgrade it is necessary to move the switch nearest the mixer two or four times a day. This causes delay.

The switch of the passing siding farthest from the mixer should be lifted, at the most, once a day or, under certain conditions, every second or third day.

Laying the track on the sub-grade is necessary when going over the bridges that have to be paved, through cuts, or in other places where there is not sufficient width of shoulder.

With a revolving crane handling a 1-yd. Lakewood clam shell bucket for unloading, it is possible to handle about 300 cu. yds. of sand and stone a day. This is sufficient to supply, to maximum capacity, a No. 14 E paver.



Plant Layout M-232

The characteristic features of this plant are: A double track siding on which material cars are received which shortens the length of yard; a movable derrick handling a 1½-yard clam shell bucket; sand and stone piles of very large size, through which is run a tunnel; and a storage house for bulk cement; and the use of two concreting outfits. The bulk cement is unloaded with a clam shell bucket and lowered through hatches in the roof of the cement storage house.

This method of storing materials provides for much larger storage capacity than Layout M-231. Sand and stone piles may be accumulated during the winter, or many months before the work is ready to go ahead. This feature enables the contractor to obtain his materials at a reduced price and eliminates shut down due to irregular deliveries.

The tunnel is built of timbers. A design will be supplied upon request. The tunnel is provided with bin gates or traps in its roof, so that a large percentage of the stored materials will flow by gravity through the traps. The cement storage house has traps in its floor.

As the trains of road cars travel through the tunnel they are loaded with sand and stone by tripping the traps in the roof. These traps are spaced uniformly so that each car is served by its own trap, thereby reducing the need for car spotting.

This plan shows how two mixers may be used on a typical road job where the unloading plant is located at a point near the center of the road job. One mixer works on a long haul *toward* the unloading plant, and the other mixer works on a short haul *away from* the unloading plant. As the haul shortens for the first mixer the track is taken up and relaid ahead of the second mixer. It is possible to use two mixers in this way when the shoulder of the road is wide enough to accommodate the track. At least 4 ft. of shoulder is necessary.

Passing sidings for cars may be laid on the subgrade, as shown at "A", or thrown over toward the ditch or into a field as at "B". The arrangement of these passing sidings must in every case be determined by the layout of the road under construction.

Passing sidings, as at "C", must be provided as close to the storage piles as possible. Others should be laid along the main road so that outgoing loaded trains may pass incoming empty trains.

This type of plant can be designed for larger capacities than are possible with Layout M-231, and an unloading plant big enough to take care of two mixers can be made a comparatively simple proposition.

The characteristics of Layouts M-231 and M-232 are interchangeable. The best arrangement of plant for any job cannot be definitely stated but should be carefully determined before equipment is purchased. Lakewood Engineers are always at the customer's service to assist in studying conditions and designing suitable plant layouts.

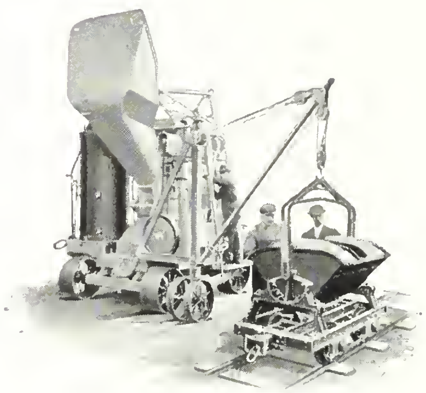


FIG. 1—Bail Attached to Car Body

a short part of the road is graded concreting can be started. This lengthens the working season considerably—usually one or two months.

By starting the grading and concrete placing at the point nearest to the unloading station, work is begun with the different parts of the job close together and under the supervision of one man. The mixer can start operating as soon as a part of the grade is finished. The hauling will not interfere with the grading, nor with the method employed in grading.

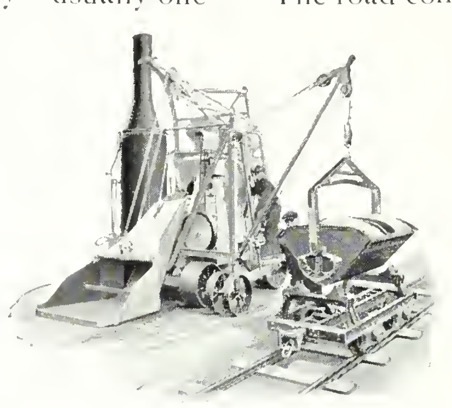


FIG. 2—Skip Lowered, Car Body Raised

In this way the job is begun with the shortest haul and the easiest working conditions. Part of the cars and track can be used for grading before they are all needed to haul material. The haul increases as the work progresses, so that the contractor can estimate, in advance, how much equipment and locomotive power he is going to need when he gets the maximum haul. And as concrete is laid during the first month of operation, the contractor is entitled to a bigger monthly estimate, thus simplifying the financing of the job.

There is no necessity for laying a considerable length of track at one time. When the long haul is finally reached, the track has been thoroughly imbedded and is better able to stand the long haul than newly laid track. In this way the grading can be completed immediately in front of the mixer and the grading and placing of concrete can be done simultaneously, throughout the entire season. This naturally lengthens the working season by beginning concrete work a month or two earlier than usual.

By not hauling over the grade a truer, more even grade is obtained and no material is wasted by filling up ruts caused by hauling. The sub-grade, once finished, needs no more attention.

The road construction track can be laid on the shoulder of the road wherever the shoulder is at least 4 ft. wide. This makes it unnecessary to move the track as the mixer moves forward. For the same reason, where there is additional width on the shoulder, it is best to put the passing track outside of the sub-grade.

By hauling in cars on track, material can be received and unloaded the same day the grading begins. Concrete placing can begin as soon as a part of the grade is finished and can follow the grading

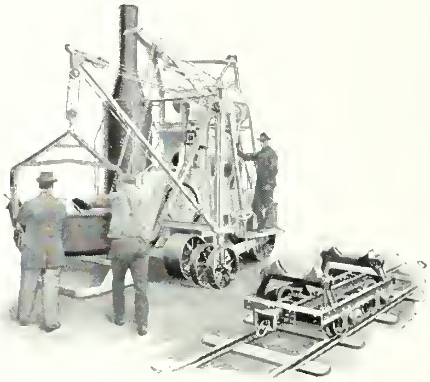


FIG. 3—Batch Swung Over Skip

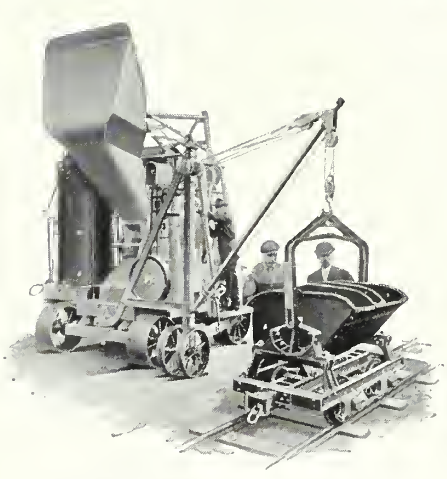


FIG. 6—Skip Raised, Car Lowered Onto Running Gear

closely. Wet weather does not interfere with hauling or placing concrete, unless it is raining so hard as to damage the surface of the finished concrete.

This regularity of consuming material reduces rehandling of material to a minimum. Many a job is shut down because of the grade becoming wet and the contractor not caring to take the chance of ordering the rest of his material when not sure that he would be able to haul it.

Where hauling is done on the grade with wagon or with motor trucks, it is always uncertain whether the unpaved earth will stand up under the travel. Often clay will make part of the haul difficult in wet weather and sand will make other parts difficult in dry weather.

Hauling on road track is an absolute certainty and it makes no difference whether the track is resting on sand or mud. By using this method a contractor should actually be able to lay concrete twice as many days in the season as he would by other methods.

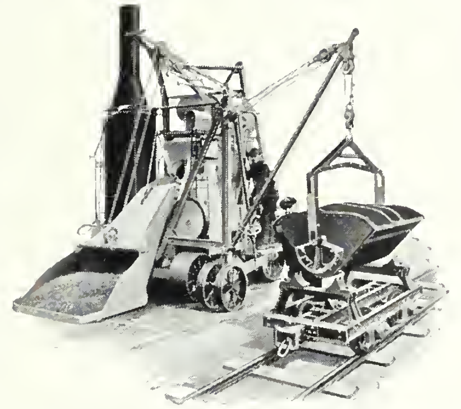


FIG. 5—Car Body Swung Back Over Running Gear

Mixing the Concrete

The operations involved in handling the complete batches as they arrive at the mixer in road cars are simplified by the use of the Lakewood batch transfer. This is a derrick arrangement attached to either side of the mixer, which lifts and dumps complete batches directly into the charging skip. **The operations are:**

1. Cement cover removed. Two men attach Lakewood bail to car body.
2. Mixer operator lowers skip. Weight of skip raises car from running gear.
3. Derrick is swung around until batch is over charging skip ready to be dumped.
4. Aggregates are dumped into charging skip.
5. Empty car body is swung back over running gear.
6. Operator raises skip to discharge batch into mixer. As skip rises car body is lowered onto running gear. Bail is detached. Cycle of operation is repeated.

By using this method complete and correctly proportioned batches are dumped

(Continued on page 16)

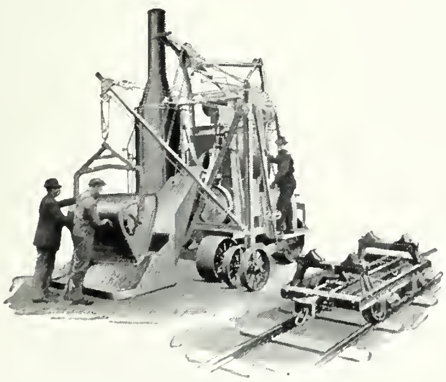


FIG. 4—Complete Batch Dumped into Skip

Compare These

The OLD *Way*

Big wheelbarrow and shovel crews.

Sand and stone piled on grade.

Aggregates become mixed with dirt of sub-grade.

5 to 10 per cent. loss of material.

Concrete work delayed until great quantity of material can be stocked on sub-grade. Working season shortened.

Sand and stone hauled over finished sub-grade in trucks or wagons.

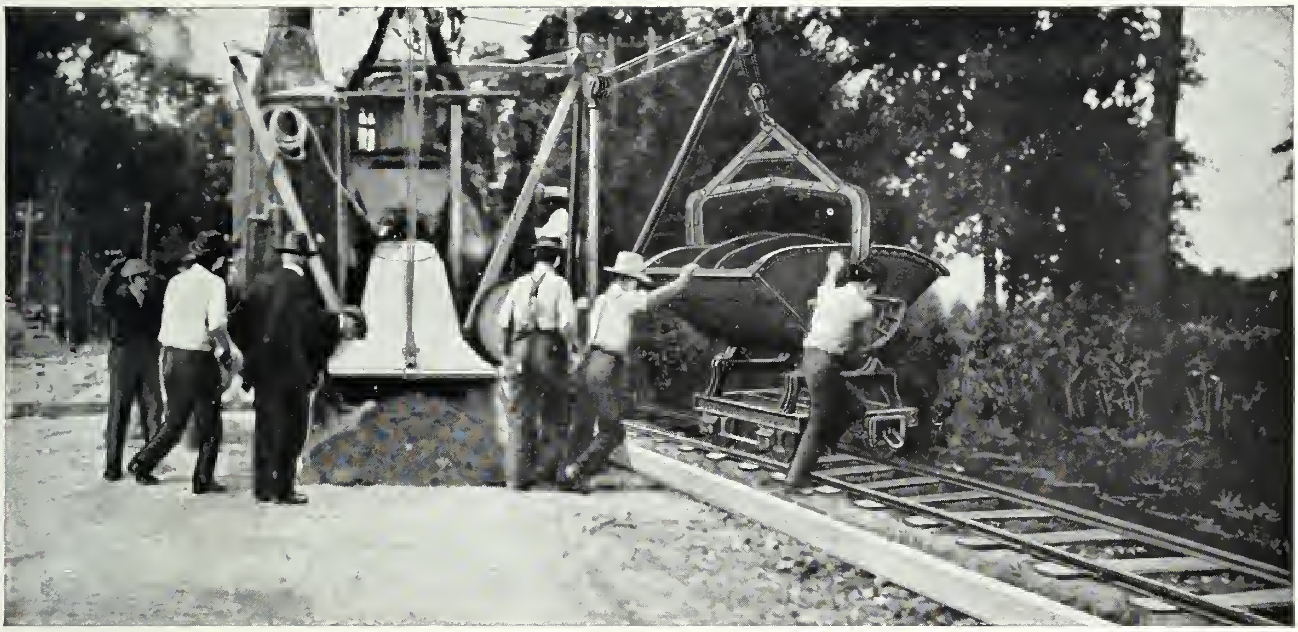
Certain amount of refinishing necessary.

Cement sacks must be cared for, increasing the contractor's cost.

Cannot operate in wet weather.

Operation difficult on narrow roads and only a small amount of road can be finished in a season.

Which Method



Two Road Jobs

The
LAKEWOOD
Way

No wheelbarrow or shovel crews.

No stock piles on sub-grade.

Batches dumped from cars into charging skip.

Clean aggregate assured.

No waste of material.

Concrete placing begun as soon as grading is started. Working season practically doubled.

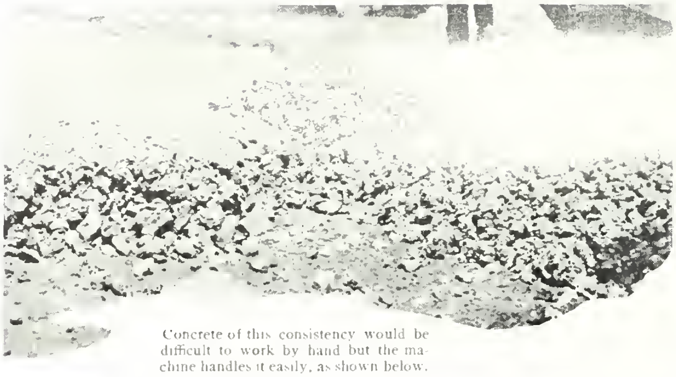
No hauling over sub-grade. Once finished, the sub-grade needs no further attention.

No cement sacks on the job. Cement bags emptied into cars at central loading plant. Bulk cement can also be used.

Operation independent of weather conditions.

System efficient on narrow and wide roads. Can finish more than twice as much road in a season.

Will *You* Use?



Concrete of this consistency would be difficult to work by hand but the machine handles it easily, as shown below.

directly into the charging skip, shovel and wheelbarrow gangs are eliminated, and no sand, stone or cement is piled on the sub-grade. No time is lost shoveling material piles out of the way or bringing extra piles to the mixer. No material is wasted from misfiguring the amount required and shoveling the excess to one side when the mixer passes. The sand and stone are kept clean—not mixed with the dirt of the sub-grade.

As the sand and stone compartments in the road cars hold just the right amount to make a correctly proportioned batch, a uniform concrete mixture is obtained without the cost and trouble of measuring each batch.

Another big advantage of this method of charging the mixer is that the work of the men is made easier. There is no wheeling of sand and stone—no cement sacks to empty. Also, each man has certain duties which he repeats day after day. He learns to do his particular part of the work better than any other man can do it—and becomes a highly efficient workman.

The fact that the work is easier appeals to the men physically. They are reluctant to leave a comparatively easy job. The labor turnover is thus reduced and the cost of securing new men is saved.

And as the work is systematized so that each man performs just one operation and can rest for a minute or so at regular intervals, the few men required will work with high efficiency throughout the day.

Tamping and Finishing the Concrete Surface

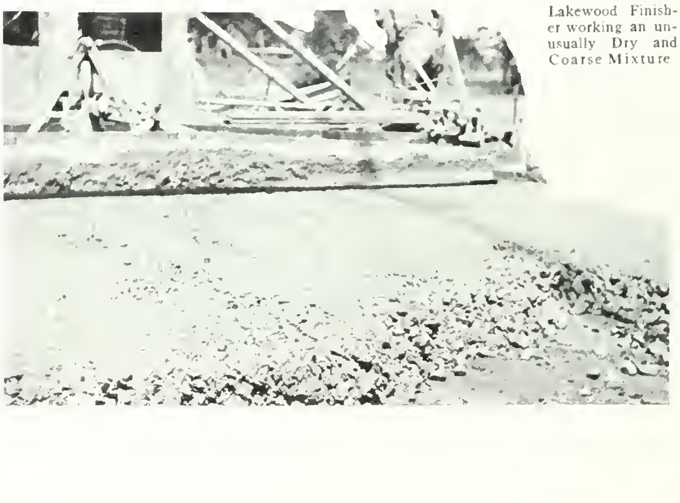
To overcome the difficulty of finishing concrete by hand and to permit the use of drier, coarser mixtures, a mechanical concrete road tamping-finishing machine has been perfected.

This device removes the air and water voids from the concrete and permits using a very stiff, dry mixture. The proportion of coarse aggregate may be increased considerably when this machine is used.

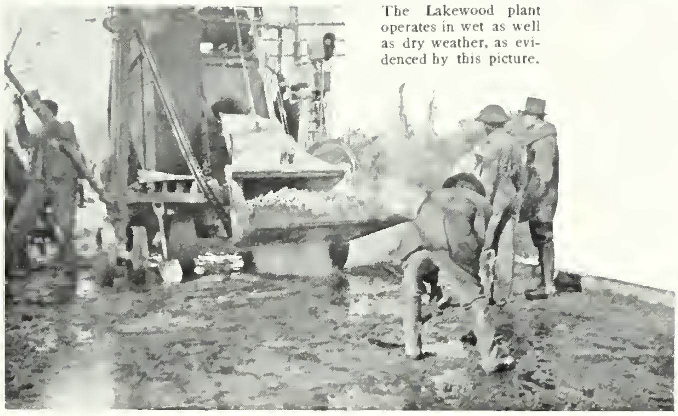
This concrete road finisher has three distinct functions:

1. To spread the concrete as it comes from the mixer to approximately the desired height and crown.
2. To tamp the concrete, remove the voids, to compact the mixture and work the concrete to the finished height and crown.
3. To float the surface of the concrete with a belt to a smooth surface.

It performs this work with a saving of labor and at a faster speed than is possible by hand methods.



Lakewood Finisher working an unusually Dry and Coarse Mixture



The Lakewood plant operates in wet as well as dry weather, as evidenced by this picture.

The machine travels forward and backward under its own power. A member called the strike-off spreads the concrete to approximately the necessary height and crown.

The tamper, located just back of the strike-off, tamps the concrete, the first time over with a long, hard stroke; the second time with a short, rapid stroke, which may be varied until the concrete is being subjected to continuous agitation as the machine moves back and forth. The stroke of the tamper is regulated by the operator and may be varied for different consistencies of concrete as well as for different stages of progress.

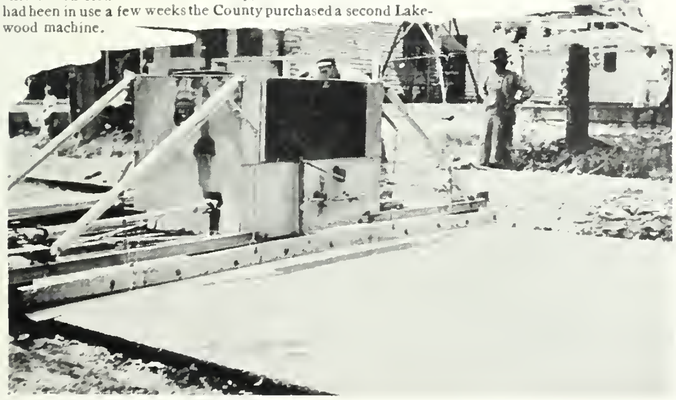
The float, located at the rear of the machine, produces a smooth finish by sweeping a belt across the surface at a comparatively slow speed. Some engineers prefer to omit the floating and have used the finisher without the belt attachment. They claim that the finish made by the rapid strokes of the tamper member is better than the surface produced by floating. The tamper finish gives a slightly roughened surface and an absolutely true crown.

By subjecting the mixture to the continuous agitation caused by the tamper the concrete is compacted and the air in it is brought to the surface as shown on page 18. The larger stones and enough mortar to cement them are brought together. By increasing the amount of coarse aggregate the contraction of the concrete is greatly reduced. The voids are thus eliminated, and a concrete of mechanically uniform consistency is produced.

This treatment, of course, results in a stronger concrete, as has been proved by Prof. Duff A. Abrams in his experiments at Lewis Institute, Chicago. Prof. Abrams has proved that 30 per cent. too much water reduces the strength about one-half and twice the correct amount of water gives a concrete of only one-fifth the strength it would have if just the right amount of water were used.

With hand finishing it is necessary to use water in large excess. If this extra amount of water is not used the concrete will be so stiff as to present difficulties in finishing. The excess water reduces the strength realized from the cement and brings the inferior materials and scum to the top, producing a poor wearing surface.

1918 Model Lakewood concrete road finisher used on the Belleville-Shiloh Road in St. Clair County, Ill. After the first machine had been in use a few weeks the County purchased a second Lakewood machine.



The Lakewood Concrete Road Finisher permits the use of a drier, coarser mixture than could be worked by hand. So dry a concrete can be worked with this that mixing can be done at a central mixing plant and the concrete hauled long distances without separation

of the aggregates. The agitation caused by the tamper is so violent that it amounts to remixing the concrete and causes more perfect hydrating of cement.

Only one man is needed to operate the Lakewood Road Finisher. Because of the arrangement of the controls the machine can be operated from either side of the road. Hence, one man with the Lakewood machine and two helpers with spades can, when working dry concrete, do the work usually done by eight or nine men—*and make a better road.*

Mixing at Central Plant

Conditions on road jobs are sometimes such that savings can be effected by mixing the concrete at a central plant and dumping mixed batches from cars onto the sub-grade. This is particularly true when concrete is laid in freezing weather —when the materials must be heated.

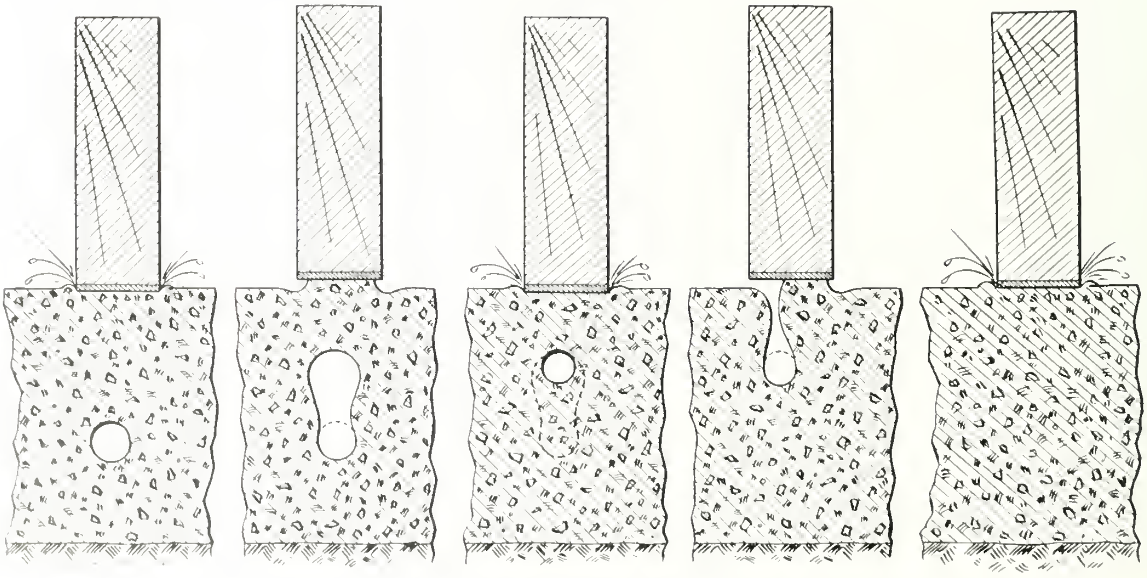
Probably the biggest obstacle to the use of this method has been working a concrete of consistency that would permit hauling any considerable distance without separation of the aggregates.

The objection that such concrete cannot be worked properly after a long haul is overcome by the use of the Lakewood Concrete Road Finisher.

So violent is the action of the tamping member that the concrete is practically remixed, resulting in more perfect hydrating of the cement and compacting the concrete after the initial shrinkage has taken place, reducing hair checks and other defects due to contraction. So dry a mixture can be used that the separation of the aggregates is practically impossible. By using such concrete so firm a surface is produced that it can be covered with straw or hay immediately.

The Lakewood road car body can be used to haul mixed concrete by removing the cement box. When dumped by a derrick this car body can be turned squarely upside down. The body being V-shaped, with a round bottom and sloping ends, dumps the concrete cleaner than any other shape of bucket.

The plant layouts shown on pages 10 and 11 may be easily adapted to central plant mixing.



Illustrating how entrapped air is removed from the concrete by alternating pressure and suction. Left to right: air compressed; air expanded in path of least resistance; air again compressed nearer surface; air bubble breaking through surface; air entirely removed.

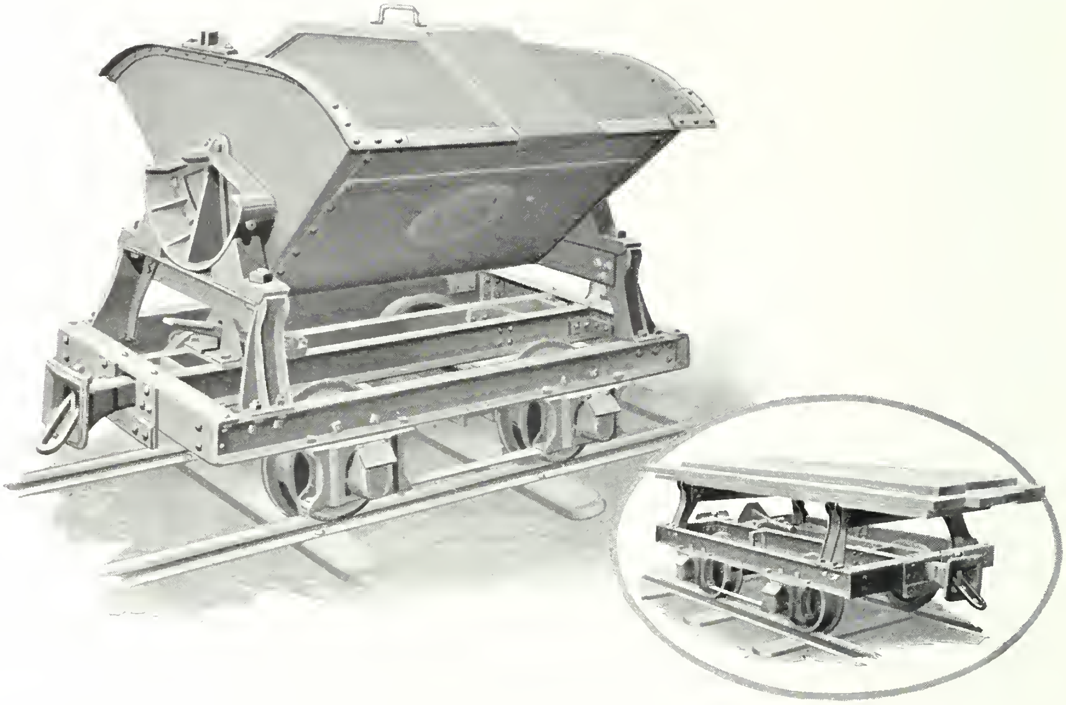
LAKEWOOD BUILT TO LAST

Equipment Used In Building Roads With Lakewood Plant

The following pages give detailed descriptions of the equipment needed for the operation of the Lakewood Concrete Road Plant.

The method of using this plant is outlined in the preceding pages. A more comprehensive appreciation of the advantages of using the Lakewood plant will be gained if the preceding pages are read carefully.

The equipment shown on pages 20 to 35, inclusive, is, we believe, best suited to do the work it is intended to do. Each unit has been designed and built to work with the other units, thus giving a complete plant that will operate smoothly and earn maximum profit for the user.



The Lakewood Road Car

This road car is fitted with a watertight cement box which is bolted into place to divide the car into separate compartments for sand and stone. In this car properly proportioned sand, stone and cement are hauled from the central loading plant to the mixer. The watertight cement compartment is bolted into the V-shaped body at a variable distance from either end of the car to give any desired proportions. The cement box is, of course, provided with a removable watertight cover.

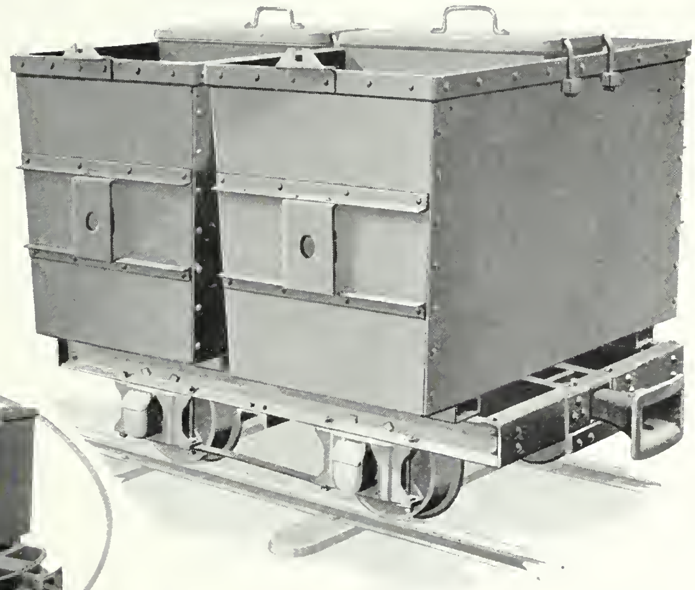
These road cars are fitted with a trunnion arrangement on the ends of the body so that the car body can be lifted from the running gear by means of the Lakewood Batch Transfer shown on page 21.

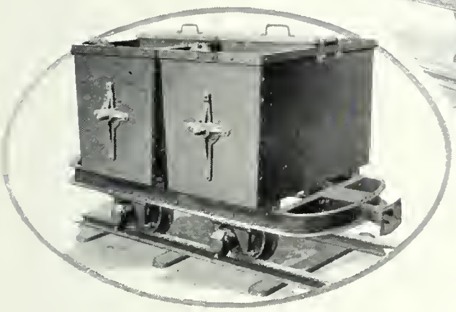
By removing the cement box the Lakewood Road Car can be used as a V-Dump car for hauling mixed concrete or dirt. By removing the body the rocker supports are used as bolsters on which to carry forms, pipe, track, etc. Thus the Lakewood Road Car is three cars in one.

These cars are equipped with spring drawbars and bumpers to permit easy starting and hauling in long trains. They are also fitted with spring pedestals to prevent derailments and reduce the shock to cars and track when hauling heavy loads.

Cage roller bearings make possible moving heavy loads with least tractive effort. Extra heavy 12-in. wheels give easy riding and hauling in long trains.

Twenty-four inch track gauge is standard.





Lakewood Batch Box Cars and Batch Boxes

Lakewood batch box cars or running gears are equipped with spring draw bars, spring bumpers, spring pedestals and Hyatt roller bearings. Heat treated steel axles, selected after a thorough investigation of the effects of rapid reversal of stress caused by locomotive haulage, insure long, uninterrupted service.

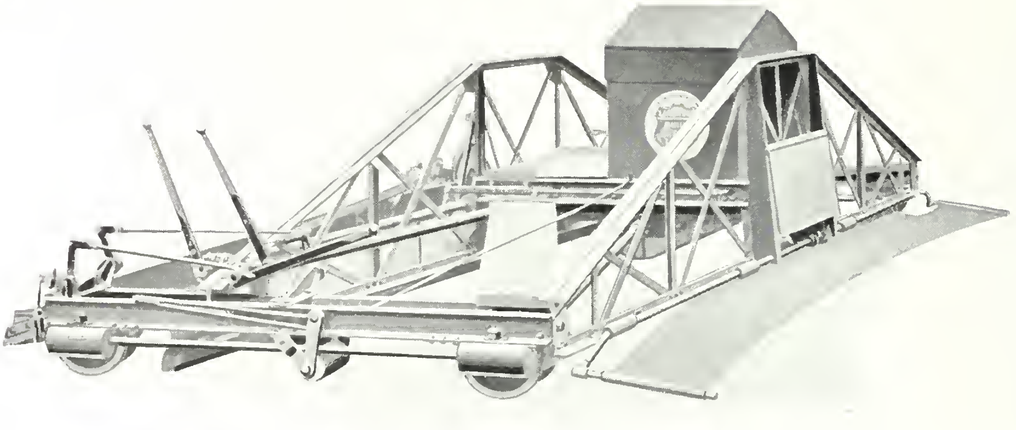
This Lakewood car represents a big advance in industrial car design.

Two sizes of batch box cars are available, one for carrying two 25 cubic foot capacity boxes, and one for two 25, 29 or 37 cubic foot capacity boxes.

The tip-over batch boxes are made of steel plate and are loaded and handled with the Lakewood batch transfer in the same manner as the road car.

A separate container for cement divides the box into compartments of proper size, which when filled with aggregates and cement, give a batch of proper size and proportions and prevents the mingling of aggregates and cement.

The small cut above shows two 25 cubic foot capacity batch boxes on the light running gear and the larger cut shows batch boxes of 29 or 37 cubic foot capacity on the heavy running gear.



The Lakewood Concrete Road Finisher

The Lakewood Concrete Road Finisher has three distinct functions: 1. To spread the concrete as it comes from the mixer to approximately the right height and proper crown; 2. To tamp the concrete to eliminate all voids, and compact the stone or gravel aggregate to give a concrete of great density and strength; 3. To finish the surface of the concrete with a belt to a smooth, even-riding surface.

It performs this work with a saving of labor, at a fast speed. The resulting concrete is more uniform as to strength and wearing qualities than is possible when hand methods are used.

The machine consists, briefly, of a trussed bridge over the road, supporting the 4 h.p. gasoline engine power plant and driving mechanism in a dust proof housing. The bridge is carried on end frames having two wheels each, traveling on the side forms.

A strike-off with a metal edge, (adjustable to the crown of the road) and having a reciprocating horizontal movement across the road is dragged by arms pivoted on the axles of the front wheels.

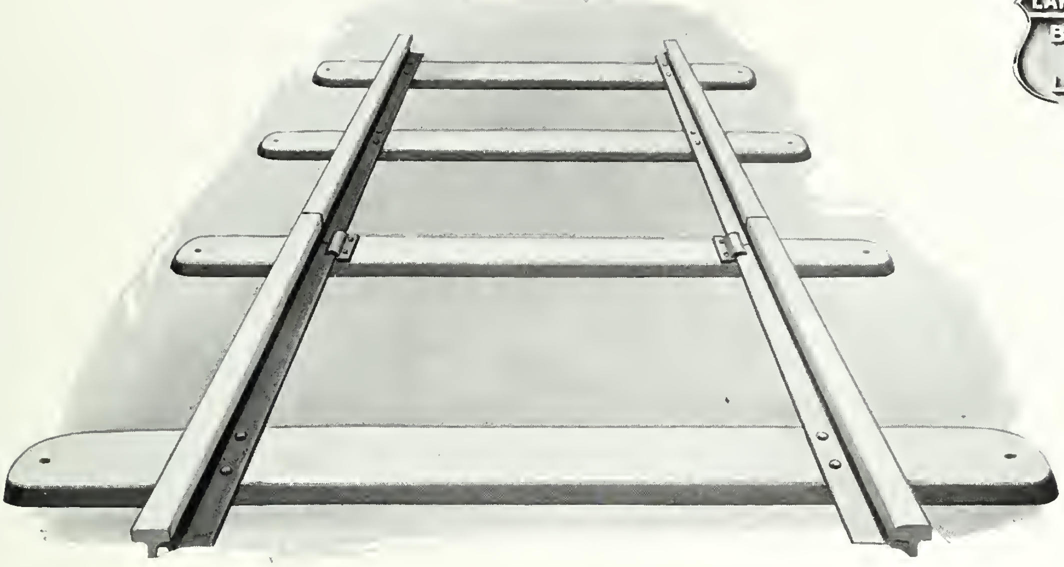
Hung behind the strike-off, on laminated springs, is the tamper. This consists of a heavy timber (kiln dried and oil soaked) shod with a steel channel. After many experiments this has proved to be the best construction for the purpose. The tamper has a snappy down-and-up movement and hits the concrete for the full width of the road with a blow, the force of which is easily varied to suit the consistency of the concrete and the condition of its surface.

The finishing belt is attached to a supporting frame at the rear of the machine, from which it is easily removed for cleaning, reversing or renewing. The frame is shaped to the crown of the road and moves the belt slowly back and forth across the road.

The finisher travels forward and backward under its own power, along the side forms. The speed forward is 7 ft. a minute; reverse, 28 ft. a minute.

All operations of the machine are controlled from either side of the road by a simple system of levers. The machine can, therefore, be easily operated by one man.

Side forms on which the machine travels may be the 2 in. boards often used, or any one of the several types of metal forms now on the market. The only requirements for the machine are that the forms rest solidly on firm ground or be supported by short stakes driven into the ground under them.



Lakewood Road Track and Joint Tie

Narrow gauge track for road work is of the most temporary kind and must be laid down and taken up repeatedly. This necessitates a track strong enough to stand this repeated rough handling. The track must also have enough bearing surface to support it on natural ground without ballast.

Lakewood Road Track meets these requirements. The rails are supported by a large, pressed steel tie with end flanges, developed for use on the European battlefields where track was laid and successfully used on extremely soft ground.

These ties are riveted to the rails to insure a rigid track section, which cannot shift by one rail taking a lead over the other, or ties slipping out of position.

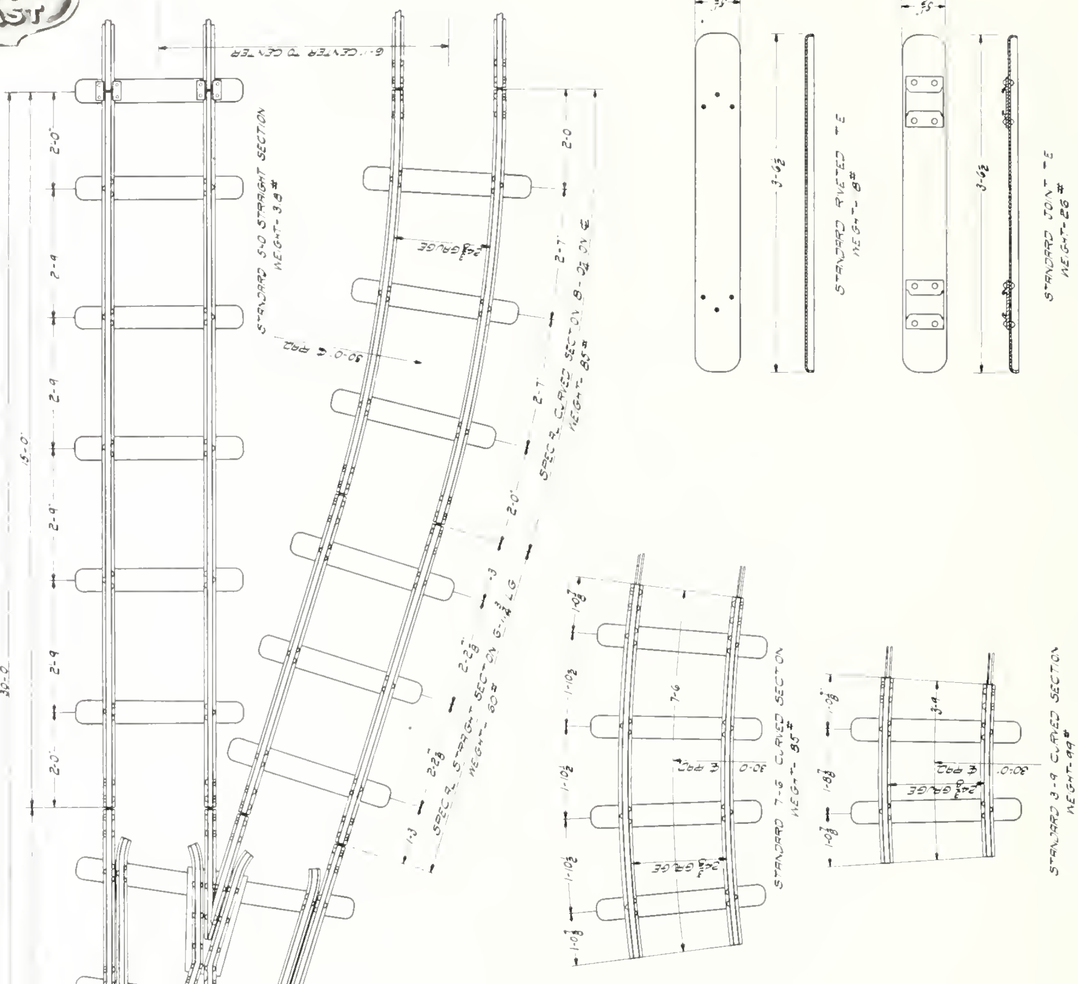
The groove in the old style rolled tie collects rain water and causes puddles under the ends of ties on the low side of the track. This softens the supporting ground at the most vital spot. This defect has been overcome by the Lakewood pressed steel tie with a flange on the end as well as on the side.

The Lakewood tie gives unusually large bearing surface outside of the rail as well as inside, thus eliminating buckling and permitting track to be used on extremely soft ground.

Frequent moving of road track makes it practically impossible to keep bolts in good shape and fish plates bolted on tightly. The common custom has been to use a slip sleeve, or simply bolt fish plates to one section. This does not make a reliable splice, nor does it support the track immediately at the joint.

To overcome these objections Lakewood has developed the joint tie shown for joining road track together. It clamps the rails and supports the joint. The tie and clamps are riveted together and make one solid piece too big to lose easily and too rugged to be damaged by handling. This tie takes the place of four fish plates, eight bolts and eight nuts—twenty pieces in all—with no threads to get out of order and no bolts to come loose.

Various track and switch sections and specifications are shown in detail on the following page.



LAKEWOOD ROAD TRACK DETAILS

The Lakewood-Milwaukee Paver

The Lakewood-Milwaukee Paver has kept pace with the growth in popularity of concrete as a material for permanent pavements. It has been improved from year to year to make possible placing more concrete of better quality in a given time.

The machine is remarkable in its design for such details as:

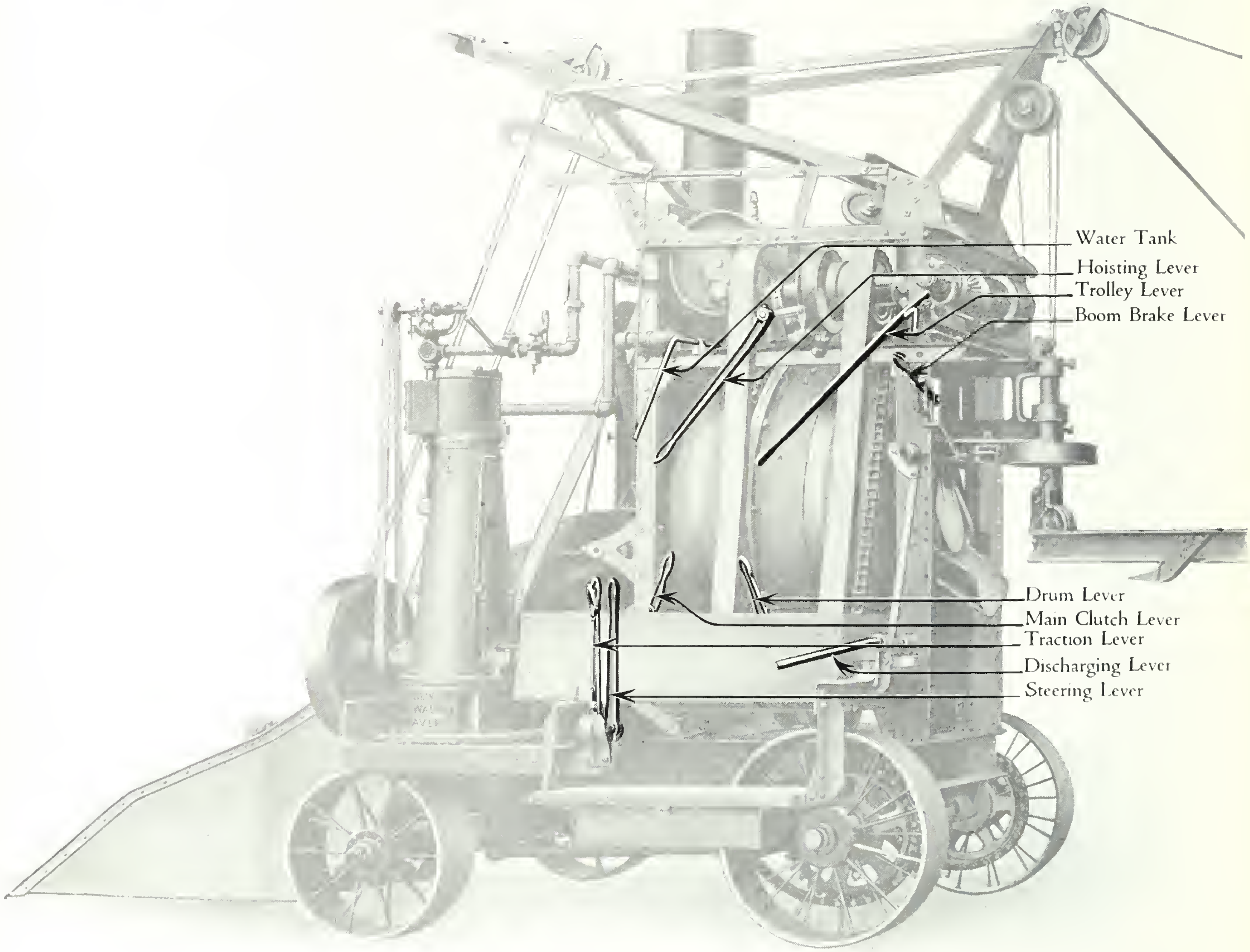
1. A differential gearing on the rear axle to permit turning in narrow streets or roads, as with an automobile.
2. A power steering device that permits the operator to guide the machine with much less effort and much more truly than with the old-fashioned hand wheel.
3. A highly developed steam engine to drive the machine, which has many unusual features, as described on page 30.
4. An unusually convenient arrangement of all levers, so the engineer can control every operation of the machine without moving around the platform.
5. Extra wide (14 in.) wheels to give large bearing surface.

Lakewood-Milwaukee Pavers are driven by either steam or gasoline power and are equipped with distributing boom and bucket or with gravity chute. The length of the boom is 16 ft. and the bucket holds a complete batch of 14 cu. ft. of mixed concrete.

The distributing bucket bottom doors are operated by a tripping and closing device developed especially for these mixers. It is not dependent on the tension of the cables, which may be comparatively slack. Any stretch in the cables is automatically taken up on the winding drums. The bucket may be run out to any point on the boom and stopped without danger of opening the bucket sooner than desired. The mechanism does not open the doors until the bucket starts on its trip back to the mixer. The doors then stay open until just before the mixer is reached, giving plenty of time for the batch to flow completely out of the bucket. There is, therefore, little danger of jamming the doors with stones. Doors are heavily braced to withstand hard service, and hinges are arranged so concrete does not overflow them.

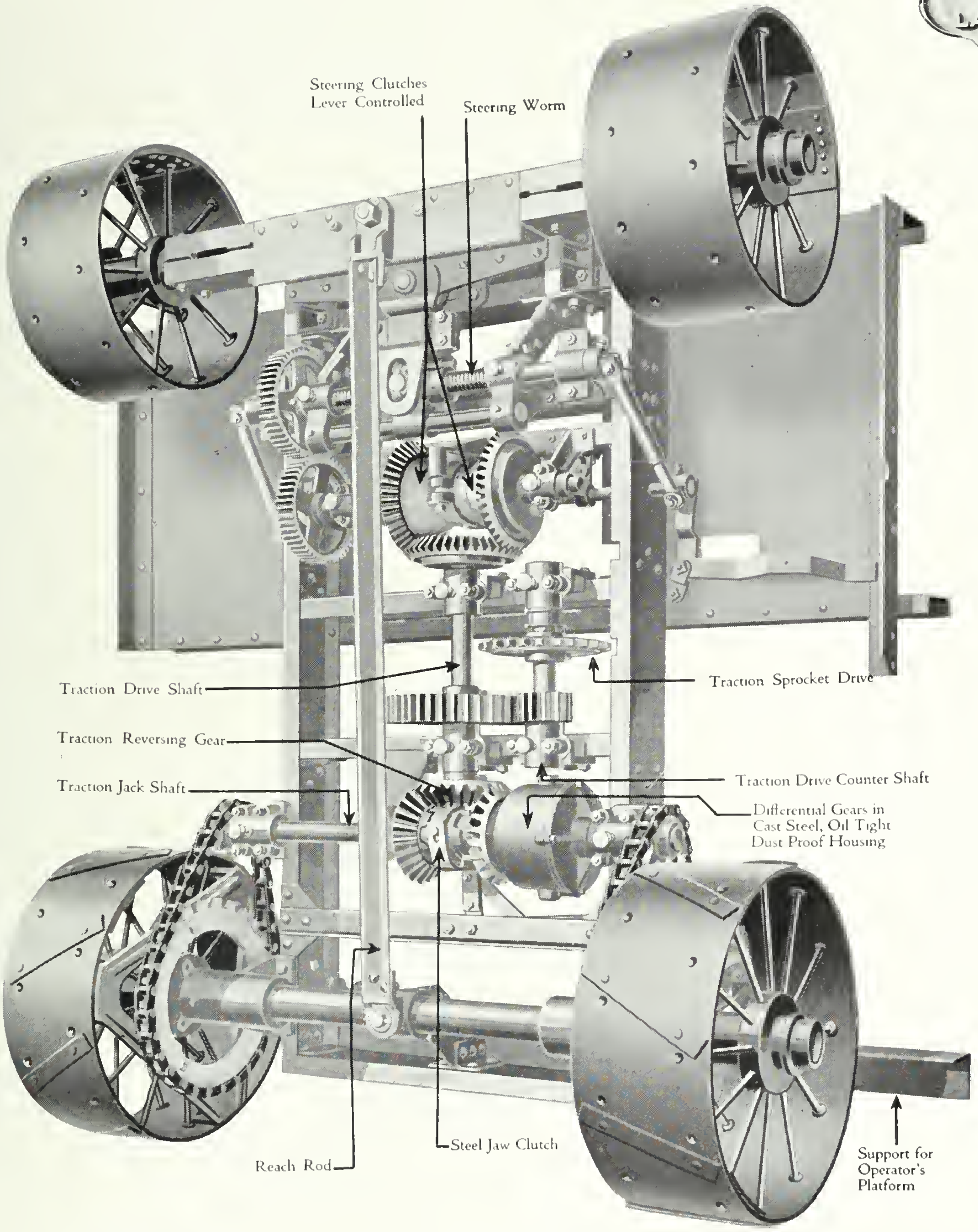
Gravity chutes are sometimes preferred on narrow street or road work. The gates are easily operated and if concrete is mixed with the proper amount of water it will easily flow down these chutes. The mixer end of chutes is widened to prevent splashing of concrete as it flows off the mixer discharge spout.

Size No. 14, with boom and bucket, is recommended for use with the Lakewood Road Plant. This has a capacity of 14 cu. ft. of mixed concrete per batch. This is the most popular size with city paving contractors putting in concrete base for various pavements. On this work the machine generally mixes a 2-bag batch of 1-3-5 or of 1-3-6 concrete.



Control Levers

All levers on Lakewood-Milwaukee Pavers are easily accessible from the operator's platform.

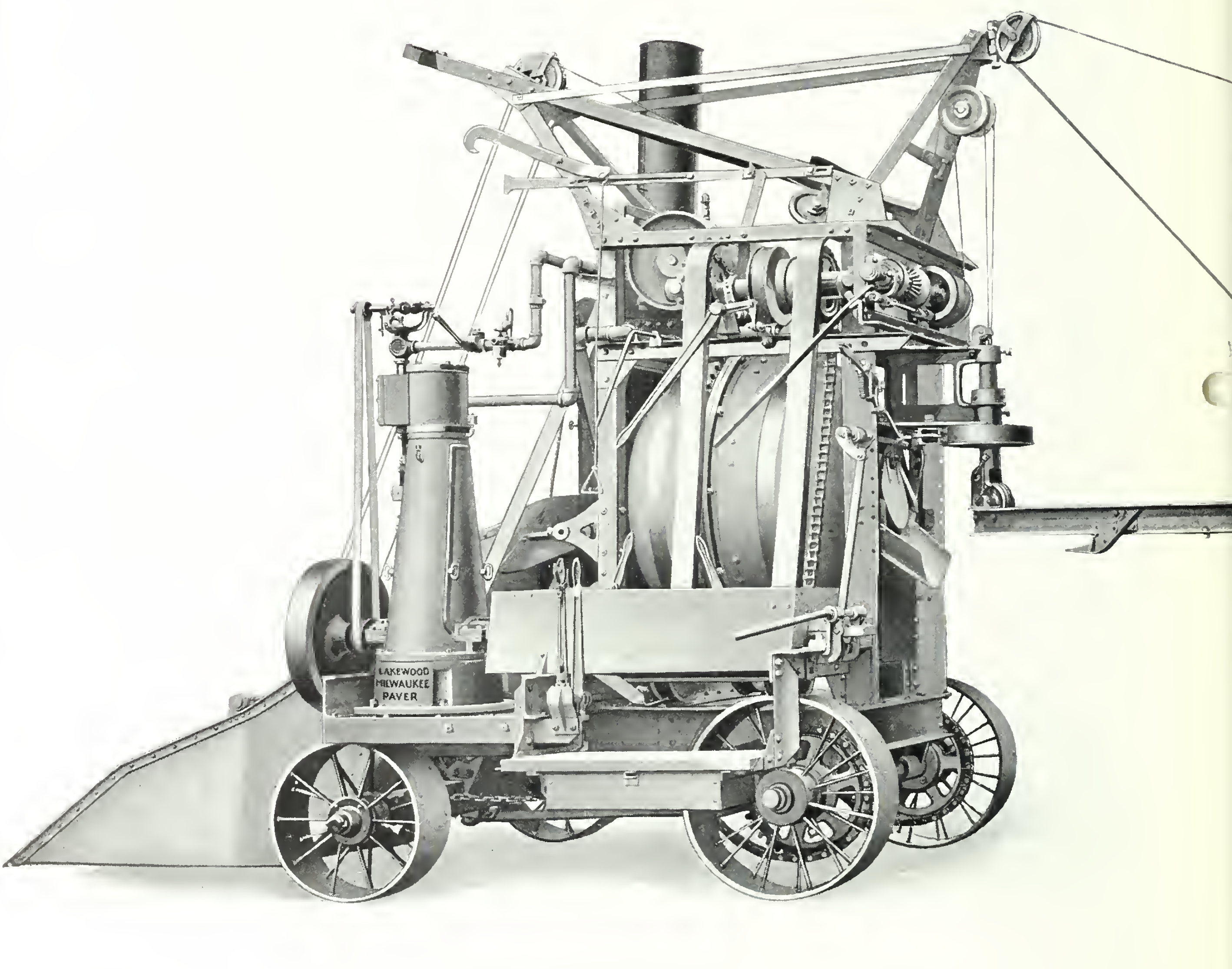


Underslung Frame Construction

Shafts, traction and power steering gears on Lakewood-Milwaukee Pavers are easily accessible. Shafts can be dropped down and removed without removing the drum or otherwise dismantling the machine.

The Lakewood-Milwaukee No. 14-E Paving Mixer

(Mixed Batch Rating)



Specifications for No. 14-E Lakewood-Milwaukee Paver

CAPACITY

22 cu. ft. of loose unmixed material.
14 cu. ft. of mixed concrete.

MIXING DRUM

Diameter, $58\frac{1}{2}$"—Length, 47"—Inside Dimensions.
End Openings, $18\frac{3}{4}$" diameter.
Tracker Surface, $3\frac{1}{2}$" wide.
Speed of Drum, 16 R. P. M.
Drive Chain.

TRACKER WHEELS

Diameter, 16".
Face, $3\frac{1}{2}$".
Length of Bearing, 12".
Tracker Shafts—Cold rolled steel, $2\frac{3}{16}$" diameter.

MAIN FRAME AND TRUCKS

Sills—8" $11\frac{1}{4}$ lb Channels—Length, 93"—Width through engine and boiler platform, 106".

Engine Platform—$\frac{1}{4}$" Steel Plate.

All-Steel Truck—3-point suspension.

Wheel Base, 85"—Tread, 70".

Front Axle, 2-6" 13 lb Channels, with built-in high carbon steel axles, $2\frac{15}{16}$" diameter.

Rear Axle Shaft—High carbon steel, $3\frac{15}{16}$" diameter

Front Wheels—28" x 14" tread.

Rear Wheels—34" x 14" tread.

Driving Sprockets bolted to rear wheels.

Cleats on wheel treads.

CLUTCHES AND COUNTER-SHAFTS

Milwaukee Internal Expanding Toggle Clutch.

Lined with non-burning automobile brake lining.

Drum Countershaft—Cold rolled steel, $2\frac{7}{16}$" diameter.
Engine Countershaft—Cold rolled steel, $2\frac{7}{16}$" diameter.

CLOSED WATER TANK

Capacity, 30 gallons.
Length, 28"—Diameter, 18".
Intake, $1\frac{1}{4}$"—Outlet, $2\frac{1}{2}$".

ELECTRIC MOTOR

Any standard make — 15 H. P. — 900 R. P. M. preferred.
Cut steel reduction gears.

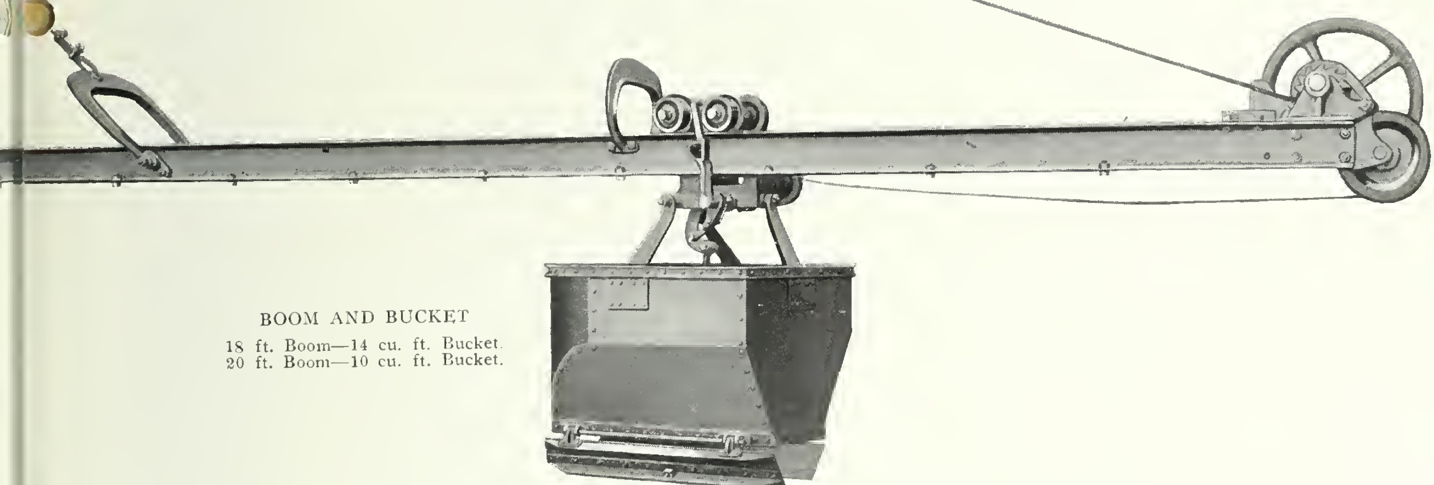
STEAM ENGINE

(See page 30)

Rated Horse Power, 12—Bore, 8"—Stroke, 8"—Speed, 175 R. P. M.
Steam Opening, $1\frac{1}{2}$"—Exhaust, 2".
Flywheel, 30" diameter x 4" face.
Crank Pin, $2\frac{1}{2}$" diameter.

STEAM BOILER

Diameter, 36"—Height over all, 84".
Rated Horse Power, 14.
Shell, $\frac{1}{4}$" fire box steel; head, $\frac{3}{8}$".
Tubes—63, 2" lap welded, 56" long.
Heating Surface—140 square feet.
Furnace, 27" high—$31\frac{1}{2}$" diameter.
Grate Area—5.1 square feet.



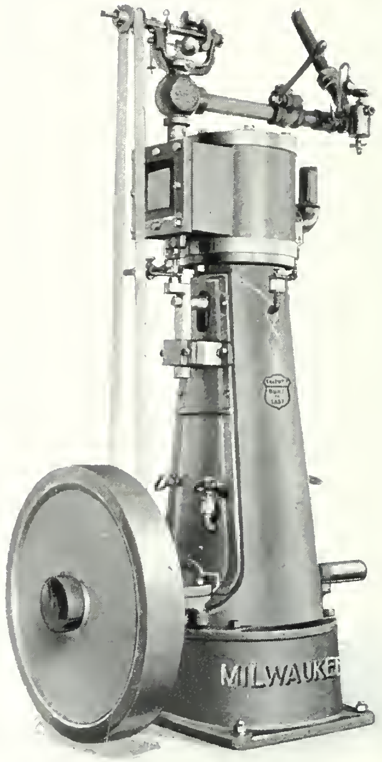
BOOM AND BUCKET

18 ft. Boom—14 cu. ft. Bucket.
20 ft. Boom—10 cu. ft. Bucket.

Traction Gearing

Travel forward or backward is controlled by only two levers at the operator's platform. One lever is for the gear shift governing the direction of travel and the other lever controls the friction clutch. There is a chain and sprocket drive to each rear wheel. Power is transmitted to these chain drives through a set of differential gears in a cast steel, oil-tight, dust-proof housing. The differential permits turning the machine on very narrow roads without any slipping of the wheels, thus avoiding strains on the rear axle and driving mechanism.

Lakewood-Milwaukee Steam Engines



Lakewood-Milwaukee Steam Engines used in the Pavers are of the vertical slide valve type.

The crosshead guides, center crank and connecting rod end, as well as the piston rod and stuffing box, are protected from cement and dirt by two side plates, held to a tight fit to the engine frame by hand latches. The life of the engines is accordingly greatly increased and repair bills are reduced to a minimum.

All lubricating points are easily accessible. The flywheel is of the solid disc type instead of being built as a wheel with spokes. This is a good "Safety First" feature. The flywheel is, moreover, counterweighted to balance the weight of the crank piston, connecting rod, etc., so the engine runs smoothly and without vibration.

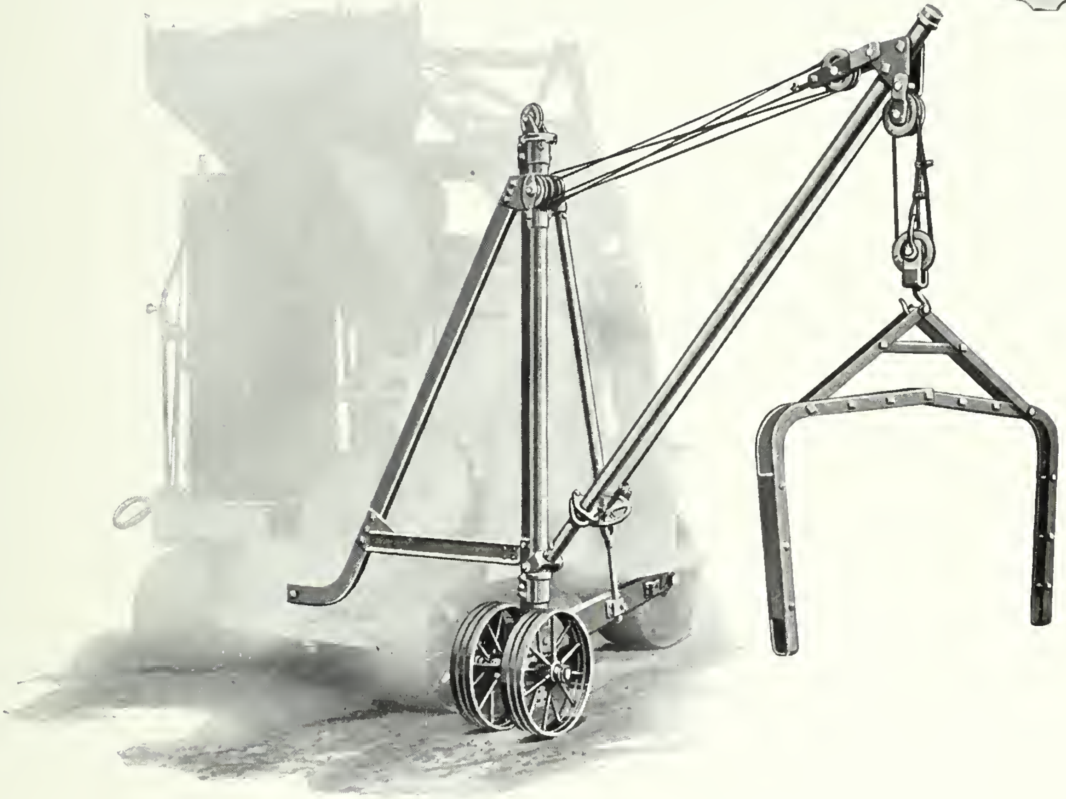
Lakewood Road Pumping Plant

To meet the needs of the paving contractor, the Lakewood Engineering Company has developed a pumping outfit which will insure a full supply of water with the chances of a shut-down of the plant reduced to a minimum.

This plant consists of two separate pumping units mounted on one truck. Each unit consists of an outside packed plunger pump driven by a Novo engine and is capable of delivering 1800 gallons per hour with a pressure of 225 pounds per square inch at the pump. The pumps may be connected so that the supply is 80 gallons per minute at a pressure of 225 pounds per square inch.

The advantages of a double pumping plant are manifest. A constant supply of water is insured, for even if one unit should break down, the other pump and engines would supply water to keep the job running.

Failure of water supply has caused many paving jobs to be shut down temporarily with a resulting loss to the contractor. The Lakewood pumping plant is good insurance that the job on which it is working will not have to be closed for lack of water.



The Lakewood Batch Transfer

The Weight of the Skip is the Lifting Force

By means of the Batch Transfer on Lakewood Paving Mixers, complete batches are dumped directly into the charging skip as discussed on pages 12 and 13.

The device permits the use of a standard front-charge Lakewood paver without incapacitating it for wheelbarrow or other methods of charging.

No extra power is required to raise and lower the road car bodies. *The lifting is done by the weight of the descending skip.* Power is thus used that would otherwise be wasted. There is no hoist to operate. Operations are timed properly and it is impossible to drop the load or raise it at the wrong time.

The derrick is carried on two wheels, as shown, thus relieving the mixer frame of any undue strains. This independent support feature permits attaching the derrick to either side of mixer in a few minutes. Any stress set up by the derrick and its load is carried by a heavy channel directly to the rear axle.

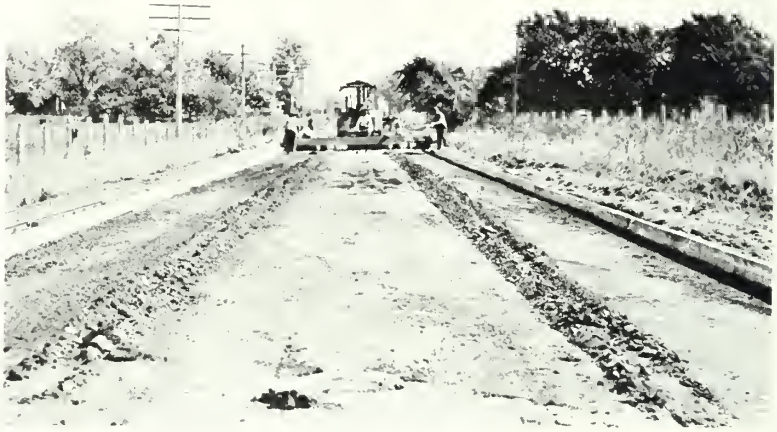
By means of a tilting adjustment, the derrick is kept in working position on varying grades, inclined so that the load will swing over the charging skip by gravity.

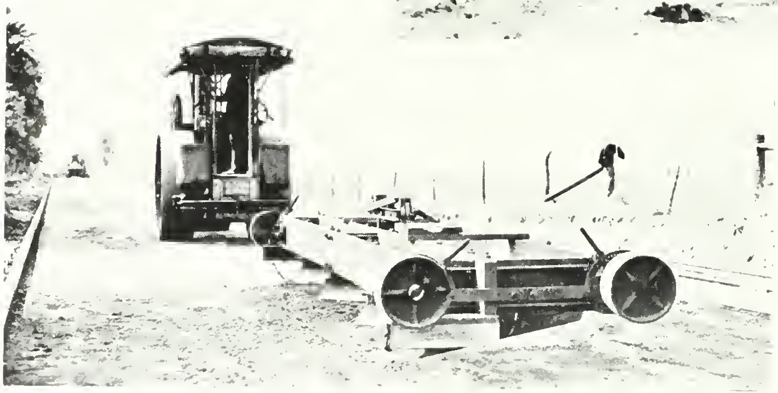
The Lakewood Subgrader

The Lakewood Subgrader was developed to provide contractors with a means of cutting an absolutely accurate subgrade at a minimum of expense.

A series of V-shaped knives 6 inches wide and varying from 2 to 4 feet in length, are mounted beneath a wooden framework. This frame is supported by rollers running on side-forms. The operation of a hand lever raises the machine on a pivot until free of the forms. It is then easily reversed or swung so that the roller may pass.

The earth shaved off by the subgrader is piled in windrows convenient for handling





The subgrader is raised and swung on a pivot to provide passing room for the roller

The same crew sets the forms and operates the subgrader. The old subgrading crew is almost entirely eliminated. There is a reduction of 50 per cent in the labor and cost of subgrading.

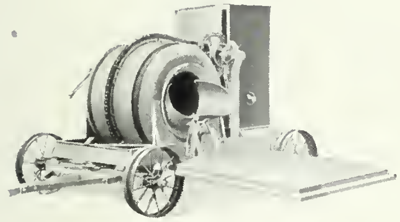
The machine is pulled by a road roller, which is a necessary part of the subgrade outfit.

While pulling the subgrader, the roller packs the loose material spread by the shovelers to fill inequalities.

The finished subgrade is true to within 1/8-inch of the engineer's profile.

There are good money-saving reasons for using a subgrader. If the subgrade is 1/2-inch low there is a waste of 146 cubic yards of concrete in a mile of 18-foot road. At $12 a cubic yard this means a loss or saving to the contractor of $1752 a mile.

Lakewood Concrete Mixers for Bridges and Culverts



LAKEWOOD-MILWAUKEE LOW CHARGE MIXER

LAKEWOOD UNIVERSAL MIXER

For culverts, bridges, footings and other jobs that are usually included in highway contracts Lakewood Low Charge or Lakewood Universal Mixers are well fitted.

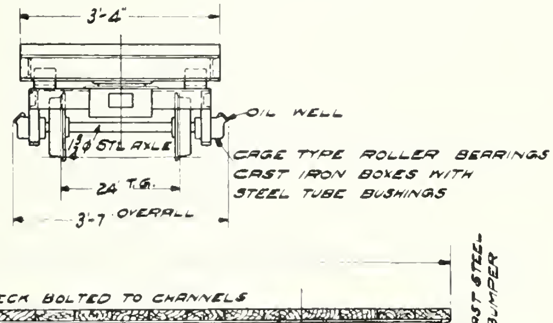
Lakewood-Milwaukee Low Charge Mixers have a capacity of 7 cu. ft. (mixed batch rating). Easily moved from job to job. Fast and thorough mixing combined with easy charging make these machines popular for this class of work.

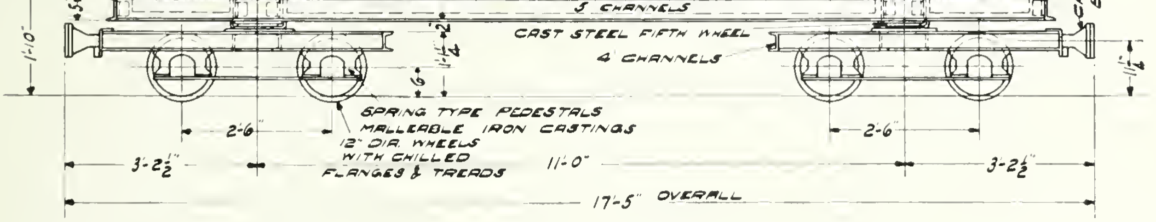
Lakewood Universal Mixers are made in only one size to hold 7 cu. ft. of mixed concrete. Machine is gear driven. Gear made of four interchangeable segments.

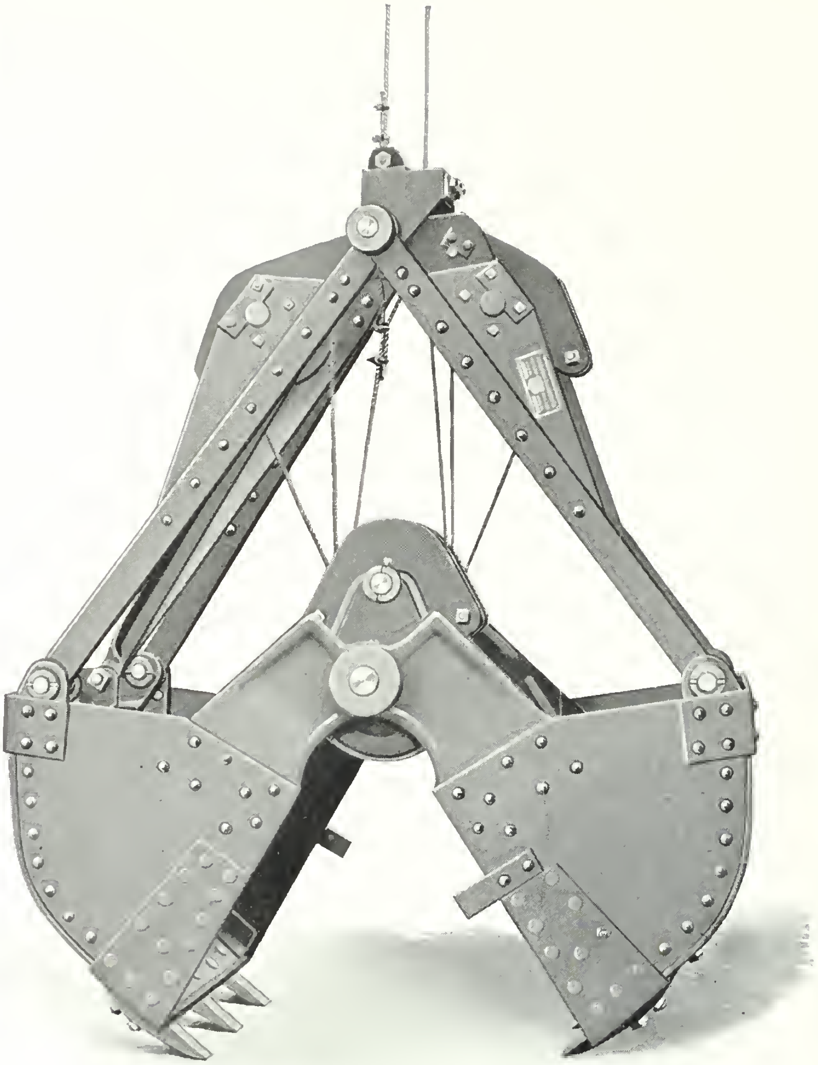
Bulletin 21 gives complete information and specifications.

Lakewood Platform Car for General Utility Work

Platform cars of the type shown are frequently used for hauling the lighter equipment, moving switches, turnouts, etc., and for transporting brick or bags of cement for culvert work. Every list of equipment should include a few of these general utility cars. Platform 16′x3′ 4″. Capacity 5 tons. Weight 2,000 pounds. Equipped with spring drawbars, bumpers and pedestals.







Lakewood Clam Shell Buckets

Diggers and Handlers

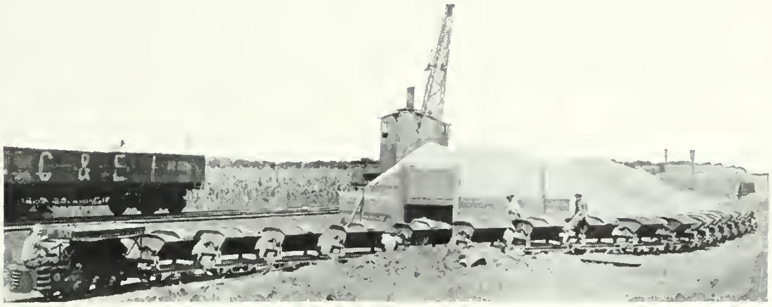
When Lakewood Clam Shell Buckets are used with a derrick or crane, in conjunction with other Lakewood Road Construction Plant, cost of unloading and handling material is reduced to the minimum.

Full loads assured because the upper sheaves are on the closing arms. This causes closing power to increase and the bucket to dig down as shells come together.

Lakewood Buckets for handling are of the same design but made lighter in weight than Lakewood digging buckets. Sizes, ½ to 2 cu. yds.

Lakewood Clam Shells for digging are made of heavier plate than the handling bucket and fitted with teeth to penetrate hard material. Sizes, ¾ to 2½ cu. yds.

Further details of Lakewood Clam Shell Buckets are given in Bulletin 26.



Lakewood Tunnel Storage

With the idea of insuring for road contractors practically continuous operation during the working season, by storing in the winter and early spring a large part of the season's supply of aggregates, The Lakewood Engineering Company in the spring of 1919 first brought to the attention of road building contractors the tunnel system of stock piles for loading and reloading concrete materials into narrow-gauge railroad cars.

The system was installed and successfully used during the season of 1919 by many contractors.

With the tunnel system train-loads of stone and sand are unloaded quickly and with the least expenditure of money and man-power.

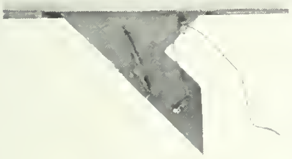
Stock piles are large enough to provide materials for the continuous operation of the mixing plant, regardless of ordinary irregularities in railroad service.

Unloading railroad cars is independent of the operation of the rest of the road building plant.

Maximum storage is obtained with the smallest amount of yard space and the shortest lengths of special sidings.

The tunnel system permits winter and early spring storage of materials—insures for the contractor the completion of finished road practically every day in the season.

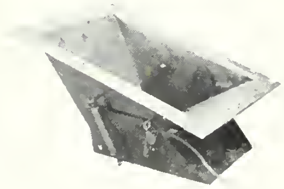
Lakewood Tunnel Traps



Side View

An important factor in the success of the tunnel method of material storage is the tunnel trap designed especially for the loading of road cars or batch boxes.

These traps are properly spaced in the roof of the tunnel, so that with one spotting of the train, all compartments can be filled with one kind of aggregate. The traps are also used successfully for charging cars from bins.



Top View

The inside dimensions of the top of the tunnel trap are 1′ 8″ by 2′ 6¾″ flange drilled for fastening to the top of the tunnel. When the trap is closed it projects 1′4⅛″ below the top of the tunnel.

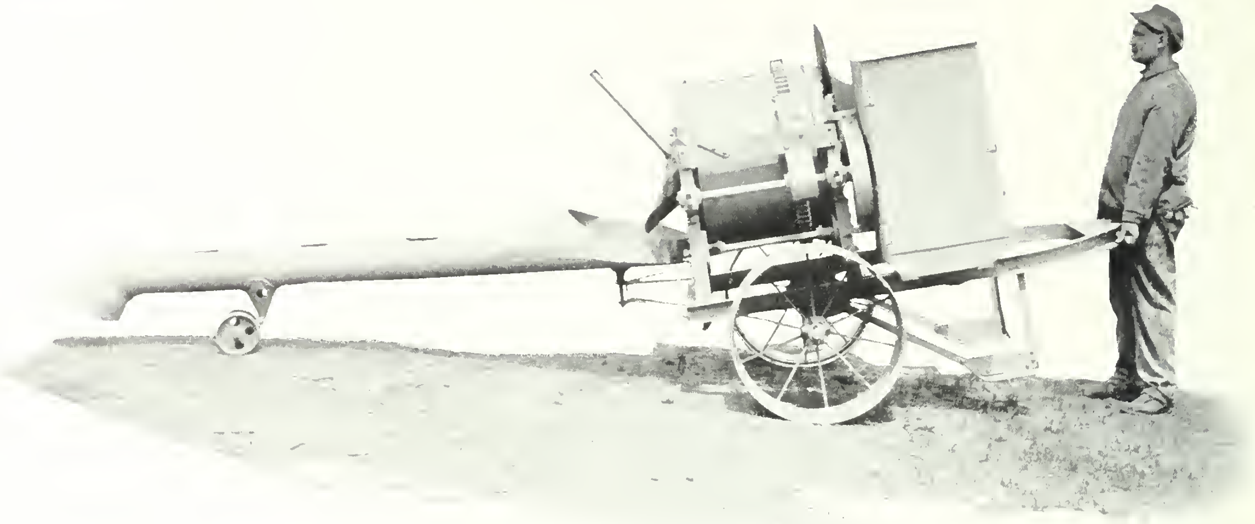
Economy of Using Bulk Cement

The Lakewood paving plant has been designed to use bagged or bulk cement with equal facility.

However, because of its economy on large jobs, bulk cement is recommended and should be carefully considered by the contractor.

The actual saving by using bulk cement has been proved to amount to as much as ten to fifteen cents per barrel. On a large job, justifying the installation of a complete plant, the cement used will be as much as 100,000 barrels, or even more, on which the saving by using bulk cement would be approximately $10,000 to $15,000.

The greatest economy will result if the bulk cement is handled by a clam shell bucket direct from gondola cars to the storage house as outlined in plant lay out M-232 on page 11. Even if the cement is shipped in box cars it can be unloaded into storage at only slightly more cost, but the economy will still be very great.



Lakewood Grouters for Brick Roads

When grout is mixed in this Lakewood M-C Grout Mixer the saving in cement soon pays for the machine. The time of 2 or 3 men can usually be added to the saving in cement. Better grout results than when hand methods are used. Described fully in M-C Bulletin 32. Immediate delivery.

Table 1

Quantity of Materials Required for One Cubic Yard of Rammed Concrete, Based on a Barrel of 4 Cubic Feet of Cement*

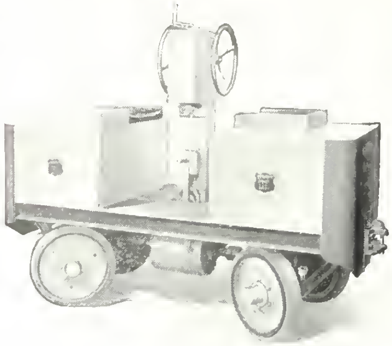
Proportion by Parts			Vol. Cu. Ft.	PERCENTAGE OF VOIDS IN BROKEN STONE OR PEBBLES											
Cement	Sand	Stone	Loose	50%			45%			40%			30%		
Bags	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone
1	1½	3	5½	2.01	0.45	0.89	1.91	0.42	0.85	1.83	0.41	0.81	1.68	0.37	0.75
1	2	3	6	1.81	0.54	0.80	1.74	0.52	0.77	1.67	0.50	0.74	1.54	0.46	0.68
1	2	3½	6½	1.71	0.51	0.89	1.64	0.49	0.85	1.57	0.46	0.81	1.44	0.43	0.75
1	2	4	7	1.58	0.47	0.94	1.51	0.45	0.89	1.44	0.43	0.85	1.32	0.39	0.78
1	2½	4	7½	1.46	0.54	0.87	1.39	0.51	0.82	1.33	0.49	0.79	1.23	0.46	0.73
1	3	5	9	1.22	0.54	0.90	1.16	0.52	0.86	1.11	0.49	0.82	1.02	0.45	0.76

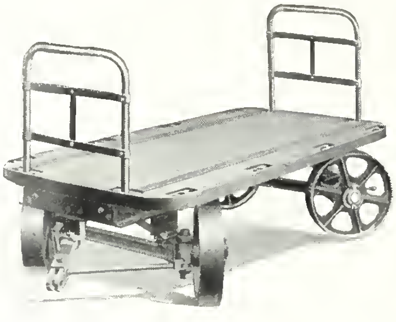
*From Taylor & Thompson "Concrete, Plain and Reinforced."

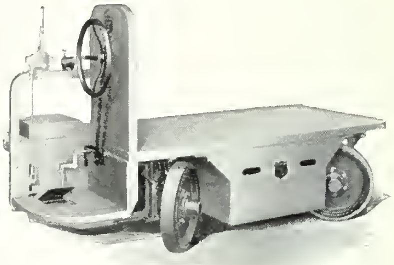
Table 2

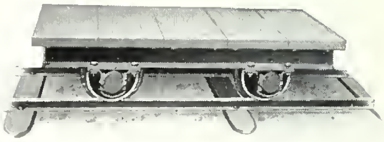
Area of Cross-Section, Cubic Yards Concrete per Lineal Foot and Mile, and Square Yards Pavement per Mile

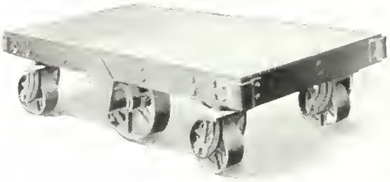
Width in Ft.	THICKNESS			Area Cross Section Sq. Ft.	Cubic Yds. Concrete per Lineal Foot of Pavement	Cubic Yds. Concrete per Mile	Square Yards per Mile
	Side Inches	Center Inches	Average Inches				
10	5	6	5.666	4.722	.175	924	5,866
10	5	7	6.333	5.277	.195	1,030	5,866
10	6	8	7.333	6.111	.226	1,193	5,866
10	7	8	7.666	6.387	.237	1,251	5,866
12	5	6	5.666	5.666	.210	1,109	7,040
12	5	7	6.333	6.333	.235	1,241	7,040
12	6	7	6.666	6.666	.247	1,304	7,040
12	6	8	7.333	7.333	.272	1,436	7,040
14	5	6	5.666	6.610	.245	1,294	8,213
14	5	7	6.333	7.388	.273	1,441	8,213
14	6	7	6.666	7.777	.288	1,521	8,213
14	6	8	7.333	8.555	.317	1,674	8,213
16	5	7	6.333	8.443	.313	1,653	9,387
16	6	7	6.666	8.888	.329	1,737	9,387
16	6	8	7.333	9.777	.362	1,911	9,387
16	7	8	7.666	10.219	.378	1,996	9,387
18	6	8	7.333	11.000	.407	2,149	10,560
18	7	8	7.666	11.497	.426	2,249	10,560
18	7	9	8.333	12.500	.463	2,445	10,560
18	8	10	9.333	14.000	.519	2,740	10,560
20	6	8	7.333	12.222	.453	2,392	11,733
20	7	9	8.333	13.888	.514	2,714	11,733
20	8	10	9.333	15.555	.576	3,041	11,733
22	6	8	7.333	13.444	.498	2,629	12,907
22	7	9	8.333	15.277	.566	2,988	12,907
22	8	10	9.333	17.109	.634	3,348	12,907











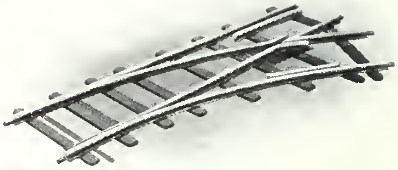
LAKEWOOD INDUSTRIAL HAULAGE

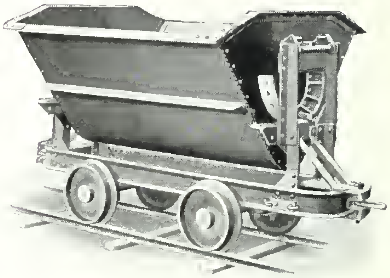
Flat Wheel and Flange Wheel

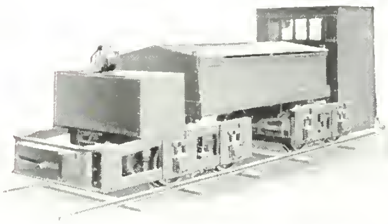
Storage Battery Tractors
Storage Battery Trucks
Four-Wheel Steer Trailers
Factory Trailers
V-Dump Trailers
Hand Trucks

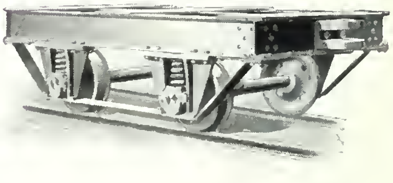
Storage Battery Locomotives
Trolley Locomotives
Industrial Cars
V-Dump Cars
Charging Cars
Core Oven Cars
Foundry Cars
Track and Switches

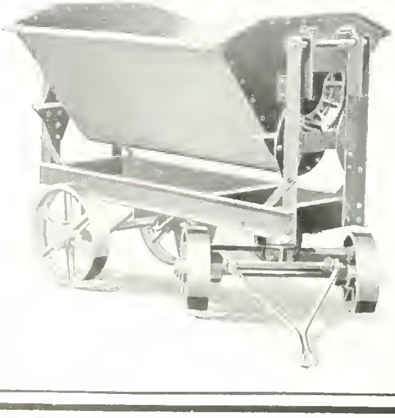
In selecting the types of haulage equipment best adapted to conditions in your plant, Lakewood Engineers can help you. A request for their service involves no obligation. Bulletins on request.

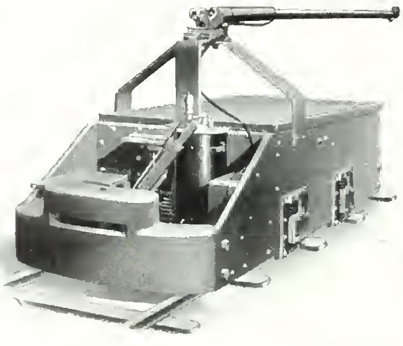


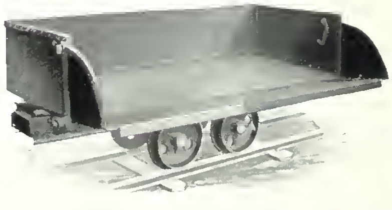


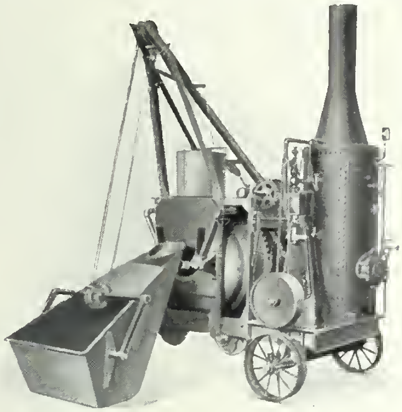


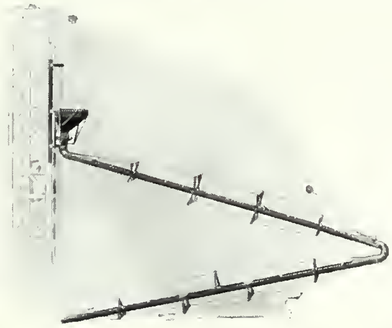








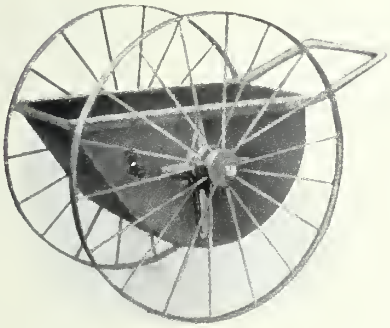


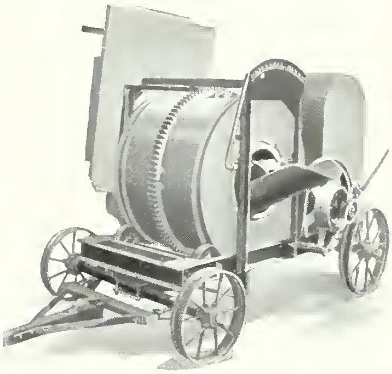


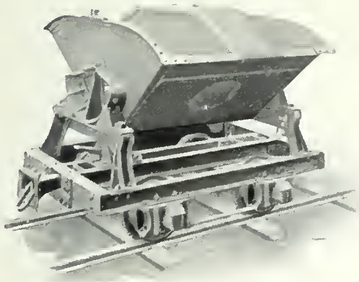
LAKEWOOD CONSTRUCTION PLANT

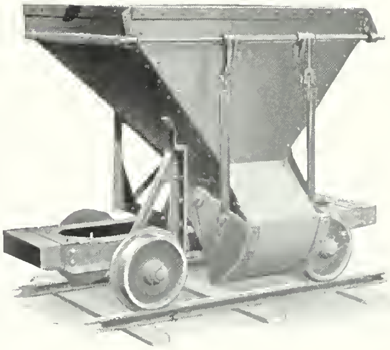
Lakewood-Milwaukee
Low-Charge Mixers
Lakewood-Milwaukee
Building Mixers
Lakewood M-C Rail Track
Mixers
Lakewood Mixers
Lakewood-Milwaukee Pavers
Lakewood M-C Grouters
Mortar Mixers
Concrete Chutes
Concrete Carts
Steel Towers
Steel Booms
Elevating Buckets
Dumping Buckets
Floor Hoppers
Skips—Sleds
Clam Shell Buckets
V-Dump Cars
Concrete Cars
Radial Gate Cars
Narrow-Gauge Portable Track,
Switches and Turntables
Concrete Road Finisher

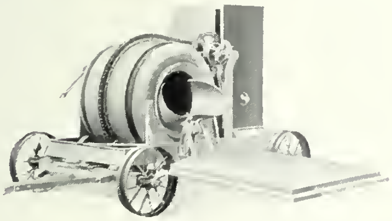
Lakewood Engineers can help select and arrange plant to earn a maximum profit for the user.

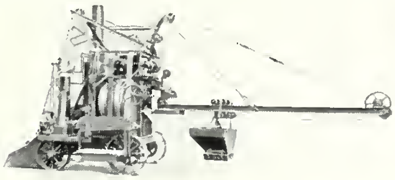


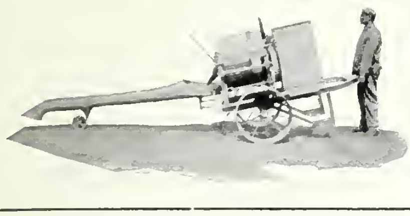


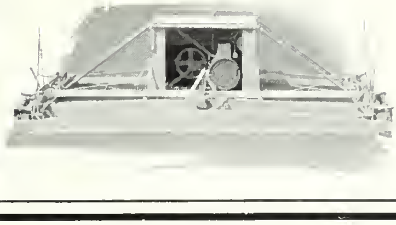


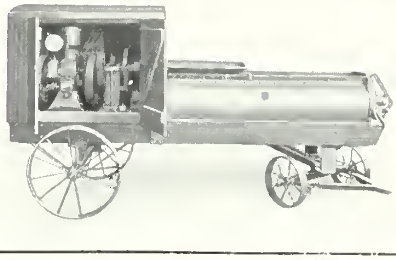












LAKEWOOD BUILT TO LAST

LAKEWOOD Road Plant operates in wet as well as in dry weather. The two views at the left show Lakewood plant owned by J. J. Dunnegan on 13-mile road job in Illinois. Lower left picture shows a 1920 Model Lakewood Finisher used by Ross P. Beckstrom on the Cherry Valley Road, near Rockford, Illinois.